Evaluation of the First Roller Compacted Concrete (RCC) Dam in Malaysia

By

Muhamad Mudzaffar Bin Mahmud

Dissertation in partial fulfillment of
the requirement for the
Bachelor of Engineering (Hons)
(Civil Engineering)

December 2004

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
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Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
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(CIVIL ENGINEERING)

Approved by,

(AP Dr Saeid Saeidi)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

December 2004

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(MUHAMAD MUDZAFFAR BIN MAHMUD)

ABSTRACT

The objective of this study is to understand the characteristic of the Roller Compacted Concrete (RCC) as the new technology implemented in Malaysia dam construction. The project has enhanced student's skill in applying knowledge, problem solving skill and presenting findings at the final stage of execution. The two semesters of project duration have developed student's skill in work ethics, communication, time management, critical thinking and solution synthesis ability.

The student had selected the project proposed by Assoc Prof, Dr Saied Saiedi which is about Evaluation of the first RCC Dam in Malaysia. Upon completing this project, several visit and research has been done on the Sg Kinta RCC Dam construction site in order to obtain useful information and guide for the analysis on the RCC. The fundamental of this project are the RCC research and application as a new technology in the dam construction. This report consists of four sections.

The first section describes the background of the project as well as the significant of the project and problem statement. The objectives of project also described in this section. All relevant reading materials that have been reviewed in the project will be discussed in second section. Those literature reviews provide background and basic information on the RCC and to identify the related discoveries on the previous study by the others. It will also summarize the data, theory and procedure gathered in the literature review. In the third section, it will discuss briefly on the methodology in completing the project during the timeframe of fourteen weeks. Next, in the fourth section, it will emphasize on the result of the RCC related experiment and discussion on the RCC mixture proportion. It will also discuss the recent progress of the Sg Kinta Dam Project construction. Later, this report will be concluded with conclusions and recommendations of the study.

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Last but not least, the author would also like to thank to all his colleague and family whom have been encouraging and helpful throughout this project.

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1.1. Project Background

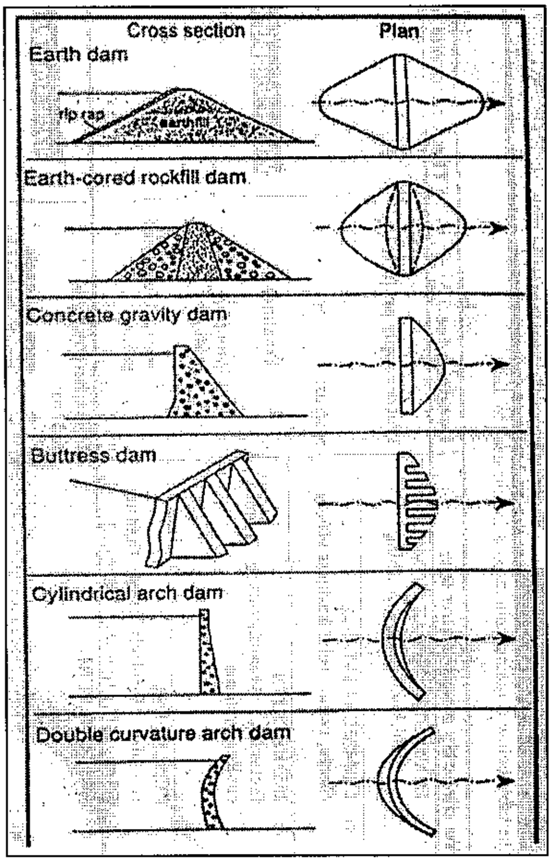
1.1.1. Introduction

Dams have been built for thousands of years - dams to manage flood waters, to harness water as hydropower, to supply water to drink or for industry, or to irrigate fields. Dams have solved many problems of communities and have provided a basis for economic development that has sustained itself. Employment opportunities have been generated, incidence of poverty has been reduced, rural populations, including nomads, have been stabilized locally and migration of rural unemployed populations to urban centers have been reversed. Food security to ever growing populations, protection from floods and droughts to chronically vulnerable areas and generation of the cleanest form of energy, namely hydropower, are some of the other benefits of water resources development. Many urban and industrial centers have been provided with water supply for consumption and transport of waste for treatment.

The dam structure is classified as a large dam if the height is more the 15m or reservoir volume is more than 3 million m^3. Malaysia has 68 dams (1998) of which 52 are large dams (75%) while about 46 dams are being planned for future (as announced in 2003). Most exciting dams (80%) are of single purpose type: water supply, hydropower, irrigation, flood control, silt control and recreation. With respect to material and shape: 49 are earth fill (70%) 13 are concrete (13%) and 6 are rock fill dams (10%). (See appendix 3 for the details specifications of the existing Malaysia dam).

Roller Compacted Concrete (RCC) has proved adequate for many engineering applications. In the last 23 years about 200 RCC dams have been built worldwide. The same numbers are under construction and many more are in the design process. The first Malaysia Roller Compacted Concrete (RCC) dam, named Sg Kinta Dam is currently being built since January 2003, located at 21 km northeast of Ipoh, Perak. It will be 80 m height, 760m long, with 30 million m^3 of water reservoir. As this is the first RCC dam in Malaysia, a study on the RCC characteristic compare to other alternative should be made.

Table 1.1 - Type of dam



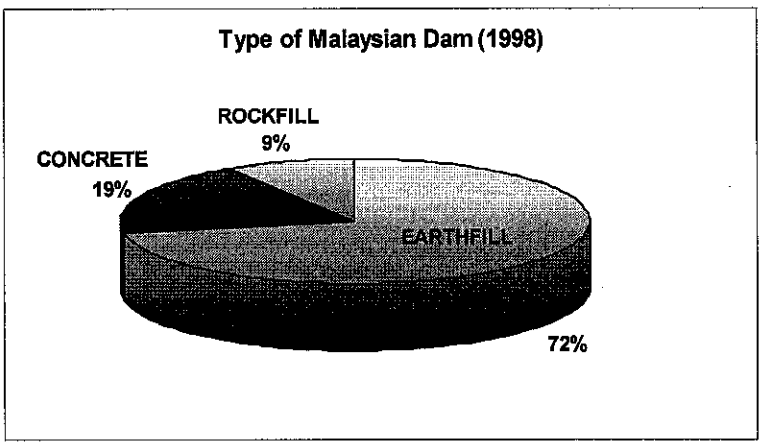


Figure1.1 – Type of Malaysian Dam (1998)

1.1.2. Significance of the Project

As this dam will be the first that use RCC technology, it is significant to understand and study the details of RCC, as in the future, Malaysia will built more dams in improving it's water resources management. RCC may be an effective alternative for the future as it offers a good material performance with a cost effective budget. The result from the stability analysis of the Malaysian concrete gravity dams will be used to analyze and evaluate the designs of the dam. Recommendations on the design will be made to improve future design and construction of Malaysian concrete gravity dams.

1.2 Problem statement

As this Sg Kinta Dam project is the first of RCC dam kind in Malaysia, much attention should be given to this first experiences to obtain lesson for future similar projects. A stability analysis of the present design will be made using software developed by Dr Saied Saiedi, which is GRACDAM. It is based on USBR Gravity Analysis Method. In order to run the analysis effectively, the existing computer program must be converted first from QBasic to Visual Basic. Apart from the analysis, a preliminary cost analysis of the design compared to some possible analysis will also be made.

Thus, intensive study must be done in order to review the advantages and differences between the Roller Compacted Concrete (RCC) and conventional concrete in dam construction. Parallel to this, literature study and experiment must be done in order to explain and study the characteristic and properties of both material and familiarize with the stability of concrete gravity dams.

During the study, the student have visited the on going construction project of the Sg Kinta Dam Project. The visits have clarified the mechanism used in dam construction and enhance understanding on the characteristic of Roller Compacted Concrete (RCC) as the main component of the dam.

1.3 Objectives and Scope Of Study

The main objectives of the project are:

- The analysis is to evaluate the general stability of the dam in term of stresses, overturning and sliding. The findings would be used to provide general guidelines for the design and construction of the future dams in Malaysia.

- To do further study on the Roller Compacted Concrete (RCC) as an alternative for the dam construction material. The study will comprise a cost comparison between the RCC and conventional concrete.

- To understand the main technology involve in dam construction and operation. Currently a lmost a ll o f the Malaysian dams are built by the foreigner such as Japanese and Australian contractor. Thus a good knowledge and understanding must be acquired by the locals for developing our own water resources systems. A good technology sharing and transformation should occur throughout the project.

The scope of the study will be limited to:

- Conducting literature reviews and research on the characteristic and properties of Roller Compacted Concrete (RCC) and conventional concrete and familiarize with the stability of concrete gravity dams. This review will also include the process of the dam construction. The review will be done through journal, published papers, online references and others.

- Conducting an analysis by using GRACDAM software, this is based on USBR Gravity Analysis Method for the RCC dam. The result will be compared to the other types of dam in Malaysia for the future studies of the concrete gravity dam.(Joint work with another student, Mr Akhdiad Hamzah)

- Conducting the experiment on the properties of the Roller Compacting Concrete (RCC).The result may be compared with the RCC that being use in the dam construction. The other thing is to compare a similar experiment result with the conventional concrete as a benchmark for comparison.

The timeframe given to complete the project is 2 semester, with 15 weeks for each part. The scope of work has been distributed within this period of time and may be referred to in the project's Gantt's Chart in the appendices.

2 ROLLER COMPACTED CONCRETE (RCC)

2.1 Introduction: History and Statistic

The use of roller-compacted concrete (RCC) originated in Canada during the mid-1970s when dry land log sorting became mandatory for the forest industries of British Columbia. RCC, a durable paving material that carries heavy loads, is now developing as a fast, economical construction method for dams, off-highway pavement projects, heavy-duty parking and storage areas, and as a base for conventional pavement.

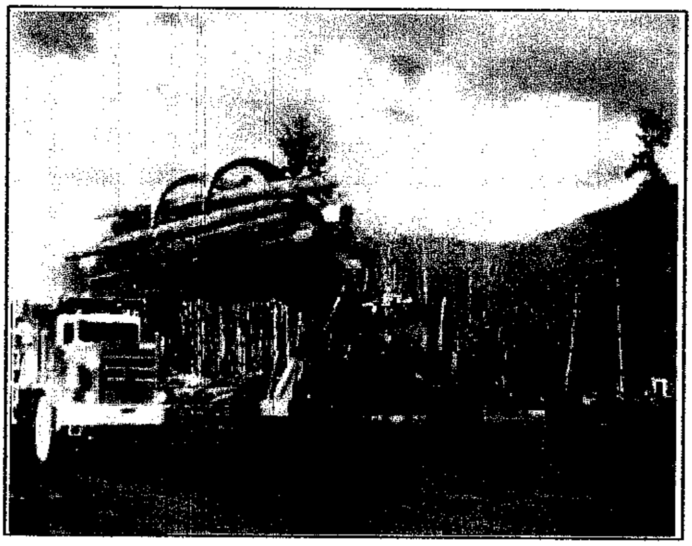


Figure 2.1 - RCC pavement at log sorting yard

RCC has low water content, requiring it to be mixed in a continuous flow system, usually a pug mill, instead of a ready mixed truck. A dump truck transports freshly mixed RCC to the construction site where workers place the mixture in layers, called lifts, using a conventional asphalt spreader. Lifts, which range from 8-12 inches (20-30 cm) in thickness, are then compacted using vibratory steel-wheel and pneumatic tire rollers. Immediately after workers complete compaction, water is applied as a fine mist to cure the concrete.

The uses for RCC paving range from pavements as thick as one meter for the mining industry to city streets, paved surfaces for composting operations, logging, truck staging areas, and warehouse floors. The procedures for construction of an RCC pavement require tighter control than for dam construction. Since the 80's the use of RCC method in construction of gravity concrete dams has been successfully applied in many important projects and helped to develop remaining hydro potential all around the world in order to cope with the increasing need of drinking water, irrigation, flood protection and energy production

Because of its low water-cement ratio, RCC typically has high strengths similar to, or even greater than, conventional concrete. RCC high-strength properties combined with ease of construction and high rate of production often make RCC more economical than a flexible pavement. Additionally, more than 20 years of exposure on logging roads in cold climates have demonstrated that RCC has adequate resistance to freezing and thawing.

2.2 RCC DAMS

RCC can be used for the entire dam structure, or as an overtopping protection on the upper section and on the downstream face. The zero slump mix is produced in a high capacity central mixing plant near the site and delivered by truck or by conveyor belt. Cement content is usually lower than that used in a conventional concrete mix, but similar to that of mass concrete. Compressive strength ranges from 7 to 30 MPa. The RCC mix is transported by trucks and conveyor belts and spread by grader or bulldozer, followed by rolling with vibratory compactors. No forms are used. On some projects the upstream face is surfaced with higher strength conventional air-entrained concrete for improved durability.

RCC dams have the advantage of allowing much steeper slopes on both faces. In addition to the advantage of using less material, the dam is completed and placed in service earlier, usually at a significant savings in overall cost compared to an earth fill structure. Other water control RCC applications include use as an emergency spillway or overtopping protection for embankment dams, low permeable liner for settling ponds, bank protection, and grade control structure for channels and riverbeds.

The principal difference between the RCC and conventional concrete is the mixture consistency and the method of consolidation. RCC has low water content and because of its low water-cement ratio, RCC typically has high strengths similar to, or even greater than, conventional concrete. RCC high-strength properties combined with ease of construction and high rate of production often make RCC a more economical construction method for the dam in the future.

Generally, there are 3 type of RCC cementitious use in dam construction around the world. In fact, most of the RCC dam is built by using high paste content RCC. Below is the classification of each RCC type.

The cementitious content is created by the difference in cement content.

1. High paste content RCC (cement content >150 kg/m^3)
2. Medium paste RCC (cement content 100-149 kg/m^3)
3. Lean RCC dams (cement content <99kg/m^3)

RCC dams have now been constructed in areas of high temperature, low temperature and heavy rainfall. For example, RCC has been placed at the 121m high Beni Haroun dam, Algeria in temperature as high as 43° C. At the Upper Stillwater, USA the air temperature drops to -35° C or lower in the winter. At Pangue dam, Chile, during the 13 months of RCC placement, there was 4436mm of rain fell during while placement continued. Thus RCC dams have now been constructed in practically all climatic conditions and in all parts of the world. This is one of the advantages compare to the other method of dam construction.

RCC is the revolution in dam design. By using conventional road construction equipment and techniques, a much drier than normal concrete mix is placed in thin layers and compacted with vibratory rollers. On recent projects, the material has been placed continuously, using conveyors. These techniques eliminate the slow and expensive process of forming and placing concrete by customary methods. RCC dams are also typically less expensive than earth fill dams. With a much steeper angle of repose on the downstream face and a vertical upstream face, significantly less material is required; often as little as 15 to 20 percent of the volume of an earth fill structure.

The design of RCC dams is essentially the same as for those made of conventional concrete. The principal differences refer to certain elements such as work strategy and treatment of joints. Construction with RCC is more economic in most cases concerning great width and length. The successful application of RCC method in gravity concrete dams has made RCC an alternative construction method in all types of mass concrete structure. At the end of 2001, there were 232 completed large dams and a further 31 were under construction.

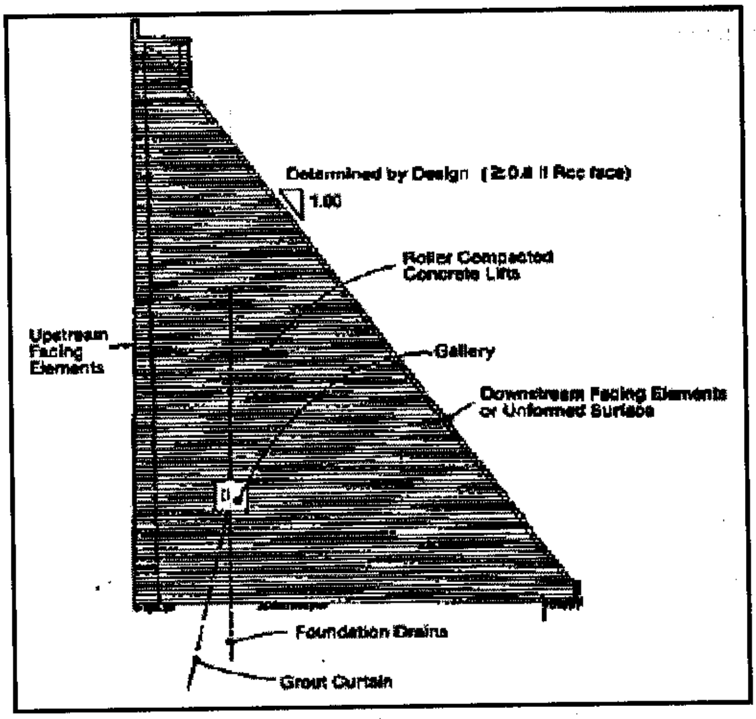


Figure 2.2 - Typical RCC dam section

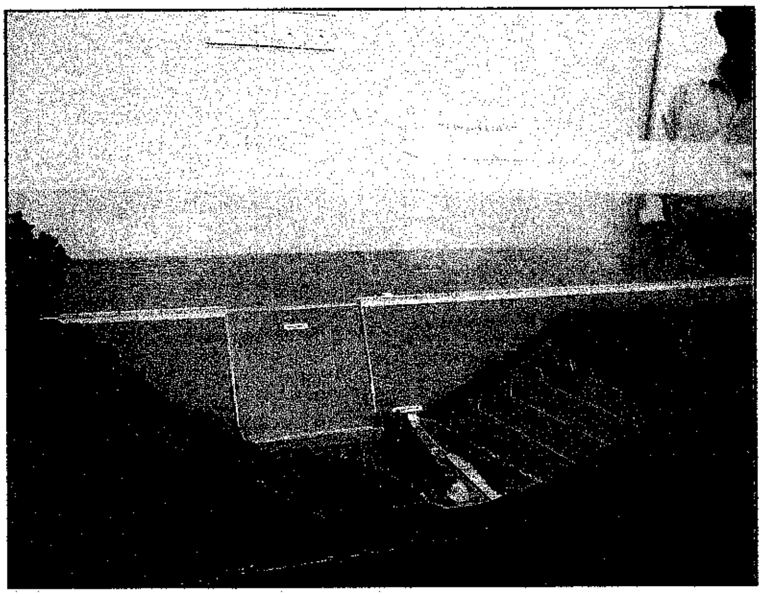


Figure 2.3 - Model of Sg Kinta RCC Dam

Concrete has played an increasingly important role in the construction and rehabilitation of dams in North America during the last 15 years as a result of the applications of RCC technology to dam construction. Since its first use in the United States in 1982 by the U.S. Army Corps of Engineers for the construction of the Willow Creek Dam in Oregon, RCC has been used to build 43 new dams, 28 of which are high dams more than 15m tall.

An RCC dam is designed much the same way as a conventional concrete gravity dam is designed: the dam material is built up to a height and depth that allows the section to resist the forces the water is expected to exert upon it by its weight. Typically, in RCC dam construction, contractors produce a no-slump concrete mix and spread it in 1-foot-thick (300 mm) layers from abutment to abutment atop a rock foundation that stretches across the waterway to be dammed.

The RCC construction method gained popularity during the 1980s because it proved to be less expensive than conventional methods of dam construction, including rockfill and earthfill construction. RCC is less expensive, in part, because it is faster.

Continuous placement of RCC is normally specified on dam projects to minimize cold joints between the horizontal concrete layers that could inhibit bonding of the concrete layers to each other. As a result a typical work schedule consists of two, 10-hour work shifts, six to seven days a week. RCC dam projects also can be completed more quickly than embankment dam projects because they require less volume of material. In addition, RCC dams allow for savings on the construction of spillways, outlet conduits, river diversion schemes, and related features that can be designed to be shorter and less material-intensive than with earth or backfill dam construction.

RCC has also become a widely accepted material for upgrading existing embankment dams to accommodate currently accepted possible maximum probable flood levels, which are often higher than the maximum flows anticipated when the dams were originally designed. RCC can be used to overlay the downstream slope of the existing embankment dam to protect the dam from erosion if the structure is overtopped by water. RCC placement in horizontal layers means that RCC overlays often take on a stair-stepped form on the sloped, downside face of the dam.

RCC has three key properties that make it uniquely suited for dams: economy, performance, and high-speed construction. It has the strength and durability of conventional concrete, but at a cost that rivals earth or rockfill construction. RCC can be used to build new dams or to shore up old ones. It protects dams from over-topping failure, earthquakes, and erosion. Sections are built lift-by-lift in successive horizontal layers so the downstream slope resembles a concrete staircase. Once a layer is placed, it can immediately support the earth-moving equipment to place the next layer. After RCC is deposited on the lift surface, small dozers typically spread it in one-foot-thick layers. Workers also place it with motor graders, spreader boxes, and paving machines.

For existing earth and rockfill dams, RCC acts like an armor plating to protect them from the erosion of high-velocity water flows. RCC can also be used to build new or replacement dams. While it's most economical for large dam projects, RCC is increasingly used to build small dams for water supply and flood control. Not only is RCC more durable than earth or rockfill dams, it's frequently more economical.

RCC has also proven itself in many other types of applications. Older concrete and masonry dams can be buttressed with RCC to increase resistance to earthquake loading and to improve stability to prevent overturning and sliding. RCC is used as backfill to support conventional concrete spillways. Due to its high resistance to abrasion, RCC is also used to construct stilling basins, build liners for outlet channels, and form grade-control structures in rivers.

Relative large quantities of RCC may be placed rapidly with minimum labor and equipment. RCC layers having a thickness 200mm or more are generally constructed in multiple layers to ensure adequate compaction of each lift. Properly constructed multi-layer RCC develop sufficient bond at the interface of the layers to be considered monolithic construction.

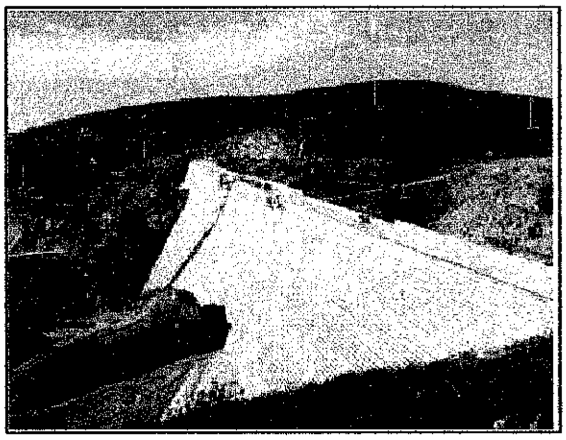


Figure 2.4 - Olivenhain Dam, California is the highest RCC dam in North America with 308 ft tall.

2.3 RCC comparison with Conventional Concrete (CC) Mix Design

From the initial study on the properties and characteristic of RCC, the data gathered shown that the Roller Compacted Concrete (RCC) perform better than the Conventional Concrete (CC) in some aspect of strength. The properties comparison data is arranged in table below:

Table 2.1 - Properties comparison of CC & RCC

	RCC	CC
STRENGTH		
-Compressive Strength (1 yr) f c	13.8 - 20.7 Mpa	equal
- Tensile Strength	0.7055*fc	0.664*fc
- Shear Strength	0.5 - 4.1 Mpa	equal
-Flexural Strength		
ELASTICITY		
-Modulus of Elasticity, (1yr) E	less	30-47 Gpa
-Poisson's Ratio	0.17 - 0.22	0.17 - 0.22
CREEP	1.5-25 MM/Mpa	-
TENSILE STRAIN CAPACITY (7 days)	20-140	40-105
VOLUME CHANGES		
-Drying Shrinkage	≤ than CC	≥
THERMAL PROPERTIES	almost similar	almost similar
-Thermal Expansion Coefficient	9-14MM/°C	9MM/°C
PERMEABILITY	1.5-150*10^{8}mm/sec	1.5-150*10^{8}mm/sec
DENSITY	slightly >	2240-2560 kg/m^{3}
DURABILITY		
-Abrasion/Erosion Resistance(72 hrs)	3-15%	almost similar
-Freezing & Thawing Resistance	<	>
OTHERS		
-Cost	< CC	>RCC
-Preparation time	Shorter	Longer

Roller Compacted Concrete (RCC) construction have an advantages as it does not need a formwork and reinforcement. It also dry quicker than the Conventional Concrete (CC), thus reduce the time required placing another layer.

Factors in strength of concrete

Although porosity is a primary facto influencing strength, it is a property difficult to measure in engineering practice, or even to calculate since the degree of hydration is not easily determined. Similarly the influence of aggregate on micro cracking is not easily quantified. For these reasons, the main influencing factors on strength are taken in practice as: water/cement ratio, degree of compaction, age and temperature. However, there are also other factors which affect strength: aggregate/cement ratio, quality of the aggregate (grading, surface texture, shape, strength, and stiffness) and the maximum size of the aggregates. These factors are regarded as of secondary importance when usual aggregates up to a maximum size of 40mm are used. Strength properties of RCC are heavily dependent on degree of compaction, aggregate quality, and cementitious content. Next, the strength of RCC is also influenced by:

- Degree of compaction
- RCC age

2.3.1 Mix Design

RCC mixture proportioning differs from those used for conventional concrete because of the relatively stiff consistency of the RCC and the use of unconventionally graded aggregates. The primary differences in proportioning RCC as compared to conventional concrete are:

- RCC has lower water content
- RCC has lower paste content
- RCC usually requires a large fine aggregate content in order to produce a mix that is stable under the action of vibratory roller.

- RCC usually has a maximum aggregates size of 20mm in order to minimize segregation and to produce a relatively smooth surface.

Table 2.2 - Example of RCC and CC Mixture Proportion

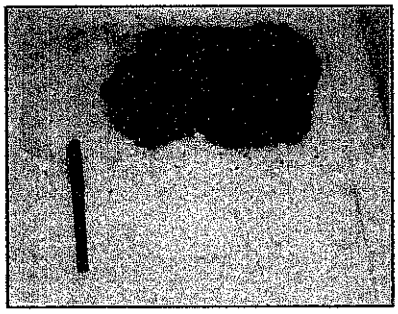
amount	RCC	CC
density (kg/m3)	2440	2400
cement	90	351.36
fly ash	90	-
G1	295.99	-
G2	423.28	616.19
G3	507.94	616.19
sand	852.8	808.02
water content	45	176

******The calculation above is based on the 1 m^3 of the sample. For the Conventional Concrete, the calculation is based on normal concrete proportion and not a concrete proportion for gravity concrete dam. The w/c ratio is 0.5.***

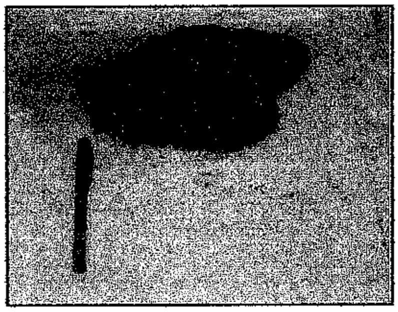
Aggregates

Aggregates that produce high strength are not always the ideal material for RCC or CC dams. On some projects, the use of aggregates of lower physical strength has produced RCC with desirable (high) creep rates, low elastic module, and good tensile strain capacity. However, the same aggregates may also produce low tensile strength and low shear properties which are important for structures in seismic areas. Caution should be exercised in using early strength results to predict long-term strength and when using marginal aggregates or other unusual materials since some materials may unexpectedly limit long-term strength properties.

AGGREGATES



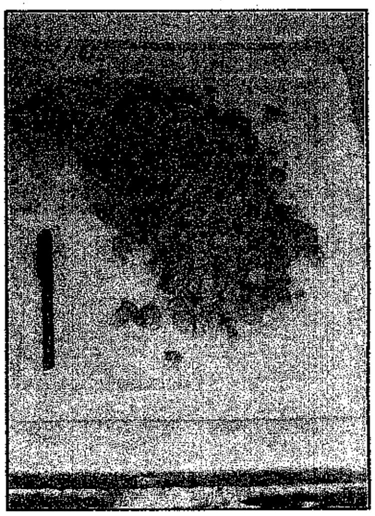
1. OPC Cements



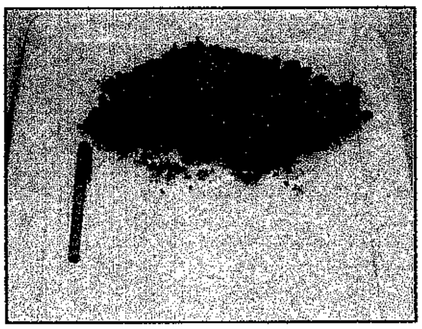
2. Fly Ash

G1 (60-40 mm)

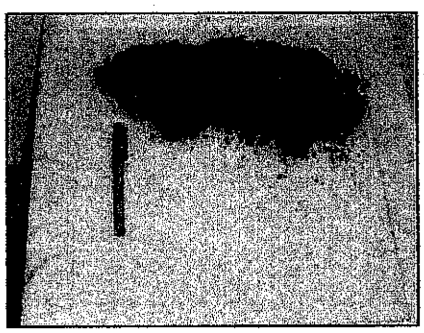
4. G2 (40-20 mm)



5. G3 (20-10 mm)



6. Mining Sand

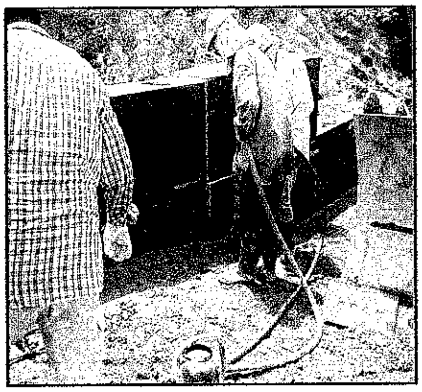


7. River Sand

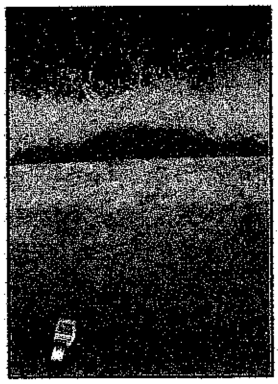
Figure 2.5 - RCC Mix Aggregate

Grout Enriched (GE)

Next, Grout Enriched (GE) RCC is also being use at the upstream/downstream and spillway surfaces. It is being used extensively for upstream and downstream facing and RCC connection to the abutment. It has high water content and OPC and very slump. The purpose is to avoid pore spaces at those parts and at the same time, enhance the strength of the dam as a whole structure.



(a)



(b)

Figure 2.6 - GE is applied on the upstream face of the dam

Bedding Mortar

Bedding mortar is used as an internal joint border between two RCC layers. RCC Dam is built by layer, which is about 300mm (12inch) thick per layer. The purpose is to improve the layers cohesiveness between both layers and prevent seepage from occur in the future.

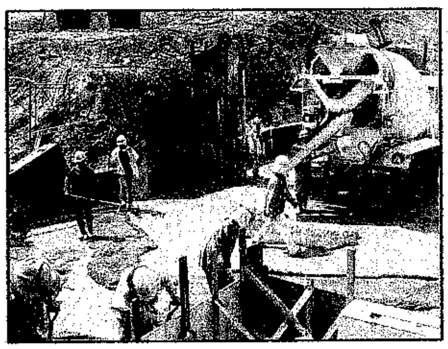


Figure 2.7 - Bedding mortar placed before the RCC placement

Enhancing Concrete Workability

The difference between fly ash and portland cement is apparent under a microscope. Fly ash particles are smaller and almost totally spherical in shape, allowing them to fill voids, flow easily, and blend freely in mixtures.

Additionally, when water is added to portland cement, it creates two products: a durable binder that glues concrete aggregates together and free lime. Fly ash reacts with this free lime to create more of the desirable binder.

- **Workability**. Concrete is easier to place with less effort, responding better to vibration to fill forms more completely.
- **Ease of Pumping**. Pumping requires less energy and longer pumping distances are possible.
- **Improved Finishing**. Sharp, clear architectural definition is easier to achieve, with less worry about in-place integrity.
- **Reduced Bleeding**. Fewer bleed channels decrease permeability and chemical attack. Bleed streaking is reduced for architectural finishes.
- **Reduced Segregation**. Improved cohesiveness of fly ash concrete reduces segregation that can lead to rock pockets and blemishes.

Increasing Concrete Performance

In its hardened state, fly ash creates additional benefits for concrete, including

- **Higher Strength**. Fly ash continues to combine with free lime, increasing compressive strength over time.
- **Decreased Permeability**. Increased density and long term pozzolanic action of fly ash, which ties up free lime, results in fewer bleed channels and decreases permeability.
- **Increased Durability**. Dense fly ash concrete helps keep aggressive compounds on the surface, where destructive action is lessened. Fly ash concrete is also

more resistant to attack by sulfate, mild acid, soft (lime hungry) water, and seawater.

- **Reduced Sulfate Attack**. Fly ash ties up free lime that can combine with sulfates to create destructive expansion.
- **Reduced Efflorescence**. Fly ash chemically binds free lime and salts that can create efflorescence, and dense concrete holds efflorescence producing compounds on the inside.
- **Reduced Shrinkage**. The largest contributor to drying shrinkage is water content. The lubricating action of fly ash reduces water content and drying shrinkage.
- **Reduced Heat of Hydration**. The pozzolanic reaction between fly ash and lime generates less heat, resulting in reduced thermal cracking when fly ash is used to replace portland cement.
- **Reduced Alkali Silica Reactivity**. Fly ash combines with alkalis from cement that might otherwise combine with silica from aggregates, causing destructive expansion.

The other advantages of using fly ash in RCC construction are:

- Less expensive to produce than conventional RCC
- Speeds dam construction
- Requires less water than conventional RCC
- Provides exceptional long-term strength and impermeability
- Reduces the heat of hydration and thermal cracking
- Is denser and easier to place and compact.

seismic reasons higher compressive strengths are often required to achieve the desired tensile and shear strength. The compressive strength at seismic strain

2.3.3 Tensile Strength

The tensile strength of RCC shall be based on the direct tensile strength tests of core samples. For the final design of new dams, cores shall be taken from test-fill placements made with the proposed design mixes, and placed with the proposed consolidation and joint treatment methods. When an existing dam is evaluated for compliance with the requirements of this EP, cores shall be taken directly from the structure. Cores should be taken vertically so that tests can be made which reflect weaknesses inherent at lift joint surfaces in addition to the tests to determine the tensile strength of the parent concrete.

2.3.4 Tensile strength Test

Splitting tensile tests are easier to perform and provide more consistent results than direct tensile tests. However, splitting tensile test results tends to over predict actual tensile strengths, and should be adjusted by a strength reduction factor to reflect results that would be obtained from direct tensile tests. When splitting tensile tests are used as the basis for determining the tensile strength of RCC, the test results shall be reduced by a strength reduction factor of 75 percent as recommended.

2.3.5 Shear Strength

The shear strength along lift joint surfaces is always less than the parent concrete; therefore, final shear strength determination should be based on tests of representative samples from the dam or test fill. Both the bond strength and the tangent of the angle of internal friction can be increased by 10 percent to account for the apparent higher strengths associated with seismic strain rates.

2.3.6 Permeability

The workability of the RCC mixture has played a significant role in seepage control, where more workable mixtures (Vebe times < 30 sec) have generally produced improved lift joint bond and water tightness. Some RCC dams constructed with less workable mixtures (Vebe times > 30 sec) (so-called lean RCC) have experienced seepage at the lift joints where segregation and/or incomplete compaction resulted in voids at the lift joint. Workable RCC mixtures can reduce compaction effort and improve compaction consistency, reducing overall permeability of the parent RCC.

2.4 Roller Compacted Concrete (RCC) Advantages and Limitations

RCC construction techniques have made RCC gravity dams an economically competitive alternative to conventional concrete and embankment dams due to the following factors.

2.4.1 Costs.

Construction-cost histories of RCC and conventional concrete dams show the unit cost per cubic yard of RCC is considerably less than conventionally placed concrete. Approximate costs of RCC range from 25 to 50 percent less than conventionally placed concrete. The difference in percentage savings usually depends on the cost of aggregate and cementing materials, the complexity of placement, and the total quantities of concrete placed. Savings associated with RCC are primarily due to reduced forming, placement, and compaction costs and reduced construction times.

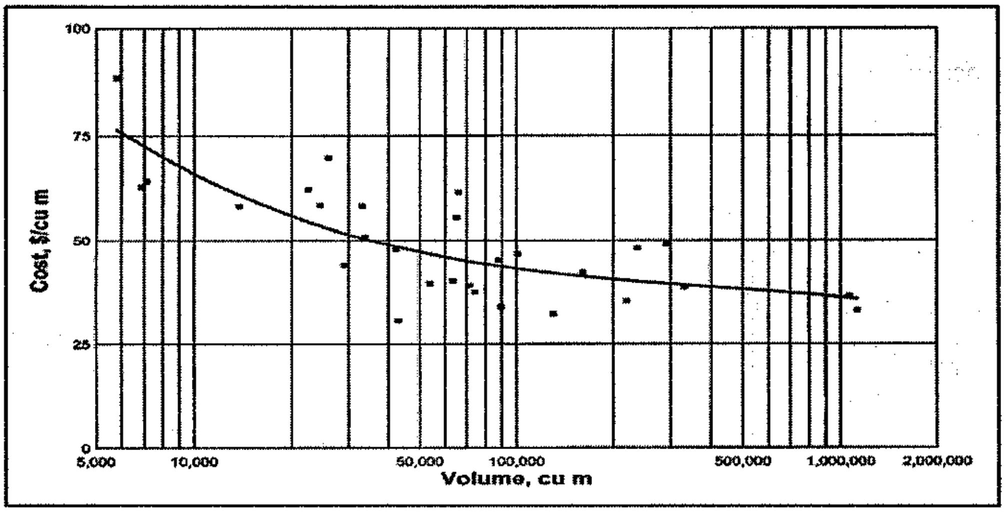


Figure 2.8 - RCC costs (1998 price level)

2.4.2 Rapid construction

Rapid construction techniques (compared with those for concrete and embankment dams) and reduced material quantities (compared with those for embankment dams) account for major cost savings in RCC dams. The RCC construction process encourages a near continuous placement of material, making very high production rates possible. These production rates significantly shorten the construction period for a dam. When compared with embankment or conventional concrete dams, construction time for large RCC projects can be reduced by several months to several years. Other benefits from rapid construction include reduced administration costs, earlier project benefits, possible reduction or deletion of diversion facilities, and possible use of dam sites with limited construction seasons. Basically, RCC construction offers economic advantages in all aspects of dam construction that are related to time.

2.4.3 Integral spillways and appurtenant structures.

As with conventional concrete dams, spillways for RCC dams can be directly incorporated into the structure. A typical layout allows discharging flows over the dam crest and down the downstream face. In contrast, the spillway for an embankment dam is normally constructed in an abutment at one end of the dam or in a nearby natural saddle. An embankment dam with a separate spillway and outlet works is generally more costly than the comparable RCC dam with an integral spillway and outlet works.

For projects requiring a multiple-level intake for water quality control or for reservoir sedimentation, the intake structure can be readily anchored to the upstream face of the RCC dam. For an embankment dam, the same type of intake structure would be a freestanding tower in the reservoir or a structure built into or on the reservoir side of the abutment. The cost of an RCC dam intake is considerably lower than the cost of an intake structure for an embankment dam, especially in high seismic areas. The shorter base dimension of an RCC dam, compared with that of an embankment dam, reduces the required size and length of the conduit and penstock for outlet and hydropower works and also reduces foundation preparation costs.

2.4.4 Minimized diversion and cofferdam.

RCC dams provide cost advantages in river diversion during construction and reduce damages and risks associated with cofferdam overtopping. The diversion conduit for RCC dams will be shorter than for embankment dams.

2.4.5 Other advantages.

When compared with embankment dams, the smaller volume of RCC gravity dams makes the construction material source less of a driving factor in site selection. Furthermore, the borrow source will be considerably smaller and may be more environmentally acceptable. The RCC gravity dam is also inherently more resistant to internal erosion and overtopping.

2.4.6 RCC Limitations

While this brand of concrete is an excellent performer, it does not provide all the features and benefits of regular concrete. These differences are not a factor in the types of applications RCC is used for.

- **Aesthetics** - RCC does not have the same appearance as other types of concrete. It is not as pretty and smooth as regular concrete.

- **Rougher Surface Texture** - The mix design and construction methods that make roller compacted concrete so fast, easy, cheap, and durable also create a surface texture that gives it a characteristic coarse finish.

2.5 Construction

2.5.1 RCC Production Controls

One of the cost-saving features of RCC is the rapid rate at which it can be placed and consolidated by earthmoving and compaction equipment. Generally, as with most other construction processes, the faster the placement is made, the less expensive the RCC becomes. In the case of a dam, the faster placement will mean less time between placement of lifts, resulting in lift joints with improved strength and seepage performance. Typical production rates may range from 35 to 150 m^3/hr (50 to 230 yd^3/hr) for a small RCC project, 150 to 350 m^3/hr (230 to 460 yd^3/hr) for a moderate-size RCC project, and 350 to 750 m^3/hr (460 to 1000 yd^3/hr) for a large RCC structure.

At Elk Creek Dam in southwest Oregon, a maximum rate of 765 m^3/hr (1000 yd^3/hr) was achieved with an average placement rate of 450 m^3/hr r (600 yd^3/hr). High production r ates m ight not be needed or even obtainable on smaller structures where working space is limited. Regardless of the size of the project, the capacities of the batching, mixing, and transporting system must be balanced to keep pace with the placement and compaction operations.

Segregation is one of the most detrimental conditions that can occur in the production and placing of RCC. Handling of materials must be controlled during each phase of the operation to minimize or prevent segregation of the aggregate.

2.5.2 Transportation Systems

The selection of a transportation system for RCC is an integral part of the design package. The quality of the lift surface is affected by the process used to transport material to the placement area. In general, high-quality lift surfaces, particularly that requiring high lift strength, are better constructed using a transportation system that uses conveyors for transportation on the dam. Vehicle placement systems are more appropriate for placements where lift surface quality and consequent lift strength are not as critical. The apparent high relative cost of the conveyor system compared with vehicle haul systems may be tempered when consideration is given to haul road logistics, placement areas, and damage control measures. Transportation systems that combine conveyor and vehicle methods have been effective on many projects.

2.5.2.1 Conveyor systems.

Conveyor systems have proven to be an efficient and safe way to transport RCC and conventional concrete from the mixer to the placement area. Conveyor systems can be configured in several ways. Simple installations convey RCC from the plant to the placement site with just a few fixed conveyors. A rotating, retractable conveyor then deposits the RCC on the lift surface via a drop chute. This configuration is ideal for small placements in tight quarters where the plant is located very near the placement area. The number and length of fixed conveyors increases if the plant is located some distance from the site. Some larger projects have utilized a continuous conveyor on the upstream face of the dam that side discharges RCC to a self-propelled conveyor or moveable conveyor capable of positioning a drop chute at any desired location.

2.5.2.2 Mobile conveyors.

Many conveyor systems have used a system of fixed belts that feed a rotating and retracting conveyor to place RCC. These systems require the addition of more rotating/retracting units to cover large placement areas. More recent implementations have replaced the rotating/retracting unit with a mobile conveyor. One method is for the RCC supply belt to be installed over the full length of the dam.

2.5.2.3 Vehicle transportation systems.

RCC can be hauled from the mixer or from the distribution point in end-dump trucks. Front-end loaders have been used in situations where the haul distance is short. Bottom-dump trucks and scrapers normally place RCC in full-thickness lifts and in longitudinal lanes. The distance that RCC can be hauled is dependent on road conditions, weather, traffic, and site topography. If vehicles are used for transporting from the mixer or from a distribution point not on the dam itself, care must be taken to prevent their tracking dirt and other foreign material onto the placing site and the damage from vehicles turning on the lift surfaces.

2.5.3 Placement Procedures

RCC has been successfully placed in lift thicknesses ranging from a minimum of 150 mm (6 in.) (compacted thickness) to well over 1 m (3 ft), although RCC lift placements in the United States have rarely exceeded 0.6 m (2 ft). Lift thickness can vary depending on mixture proportions, plant and transport capability, placement rates, spreading and compacting procedures, whether or not a bedding layer is used, and size of placement area. For most applications, an initial lift thickness of 300 mm (12 in.) is suggested, with subsequent adjustments based on results of specified preconstruction investigations. The lift thickness should be determined by the designer and specified in the project specifications.

2.5.4 Spreading RCC.

When lift thickness is limited to 300 mm (12 in.), small dozers have been successfully used to spread and level RCC. Dozer sizes range from a Cat D3 for placement rates up to 150 m^3/hr (200 yd^3/hr) to a Cat D5 size for placements up to 375 m^3/hr (500 yd^3/hr). Combinations of various sized dozers have been used to efficiently place RCC at varying placing rates. RCC should be advanced across the length of the dam for the full upstream-downstream dimension. Placing RCC in lanes must be avoided. RCC should be spread to provide a uniform surface capable of uniform compaction. Ruts, bellies, and humps in RCC surfaces should not be excessive since they prevent uniform compaction. Dozers should never operate on compacted RCC surfaces.

3 SG KINTA RCC DAM

3.1 Introduction

The Sg Kinta Dam Project is part of the Stage II development of the Ipoh Water Supply. This stage of development consists of the construction of a dam with a yield in excess of 300ML per day, associated raw water pipeline and the water treatment plant to augment the existing low weir and water treatment plant on the Sg Kinta. The site located 21 km northeast of Ipoh, Perak. The dam site rocks are primarily deeply weathered granites which vary from 'closely jointed but healed' to massive rocks. Water test result indicates that the foundations will generally be of low permeability. The RCC aggregates will be produced from the crushed granite to be obtained from quarry to be developed by the contractor about 1.2 km from the dam.

The Feasibility Study conducted by GHD and Angkasa GHD indicated that either a concrete faced rock fill or a roller compacted concrete (RCC) dam would be economic at the site. The subsequent Concept Design Report completed by GHD and Angkasa GHD concluded that the least cost dam would be a roller compacted concrete dam. The detail of the dam is attached in Appendices.

3.2 Construction

Sg Kinta RCC Dam is built based on the lean RCC dams (cement content <99kg/m^3). A relatively rich RCC mix was developed, consisting of 90 kg/m^3) cement plus 90 kg/m^3 fly ash. Vebe time for the mix was approximately below 30 seconds. The coarse aggregate was obtained from the quarry. RCC placement began on February 17, 2004. The RCC was batched and trucked to the dam site in 7-cu-yd (5.4-m^3) loads. Average delivery time to the lift surface was approximately 10 minutes. Production rates for the early days of placement is below 500m^3, but sometimes the work was delayed due to other difficulties such as weather. After the contractor got off the foundation and became familiar with placement, the production rates will increase

The 24 hour placement will commence beginning mid of May 2004. So the works that behind planned schedule will be covered soon after it begin. Up to date, the progress is fall 3 months behind proposed schedule. The details of the work progress is summarize in Figure below.

Sg Kinta RCC Dam is very significant to the Malaysia Dam development as this is the first of its kind built in this country. Another thing is that this dam is believed to be the first RCC Dam in the world that will built through monolith system, which will be placed layer by layer with 300mm thickness and 3m height at a slope of 1:10, from on side abutment to the other side. This technology will enhance the speed of the construction process.

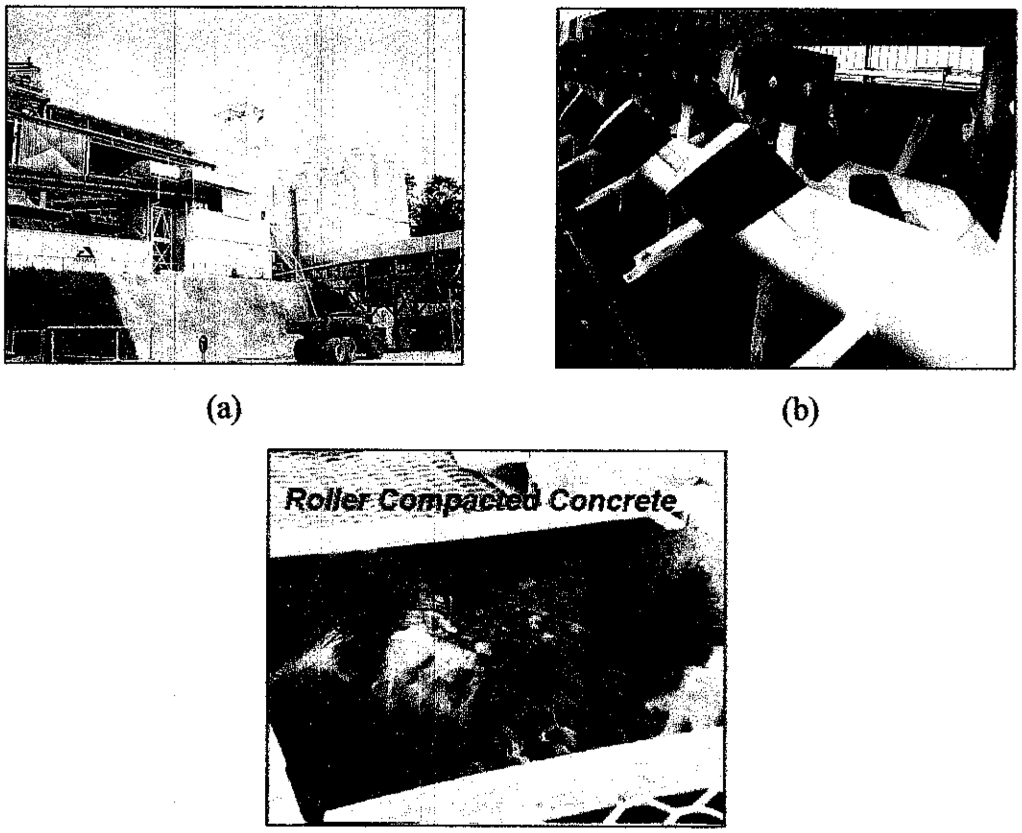
RCC Mixing Plant

Sg Kinta RCC Dam use Aran machine system for mixing the c oncrete. A ran systems are recognized across the world for the integrity of their metering systems and the thoroughness of their mixing. They are designed as integrated systems with consideration to the characteristics of the materials being metered and mixed. This machine has been applied to major infrastructure projects in remote locations across the globe. Recent examples are a 1 million cubic meter roller compacted concrete dam in Colombia and a 400,000 cubic metre concrete paving project for a NATO base in the UK. Because Aran machines are designed for easy cleaning and maintenance with durable and reliable components, we are able to support them without need for a service presence nearby.

A "through (or continuous) mixer" is quite different in operation from a batch mixer. A batch mixer is called upon firstly to uniformly disperse disparate ingredients from different zones of the mixer and then to finely divide them into a homogeneous mass. "Through mixers" work on the presumption that the ingredients are all correctly proportioned one to the other by the metering system before they enter the mixer and are in effect "ribbon fed". The "through mixer" has only a modest task of "macro mixing", and can devote most of the mixing effort to "micro mixing". A "through mixer" at any instant can only mix ingredients in the proportion in which they are received. It can not add missing amounts of an ingredient and has only a limited smoothing effect on erratically fed input materials. A well designed "through mixer" with uniform in feed will produce a more finely divided and uniformly mixed end product than a batch type mixer for the same amount of mixing effort.

Key Benefits

- High Production Rates
- Accurate Metering and Mixing
- Homogeneous Mixing
- Modular, Transportable Construction
- Reliable and Serviceable Design



(c)

Figure 3.1 – Mixing of RCC at the Aran Mix Plant

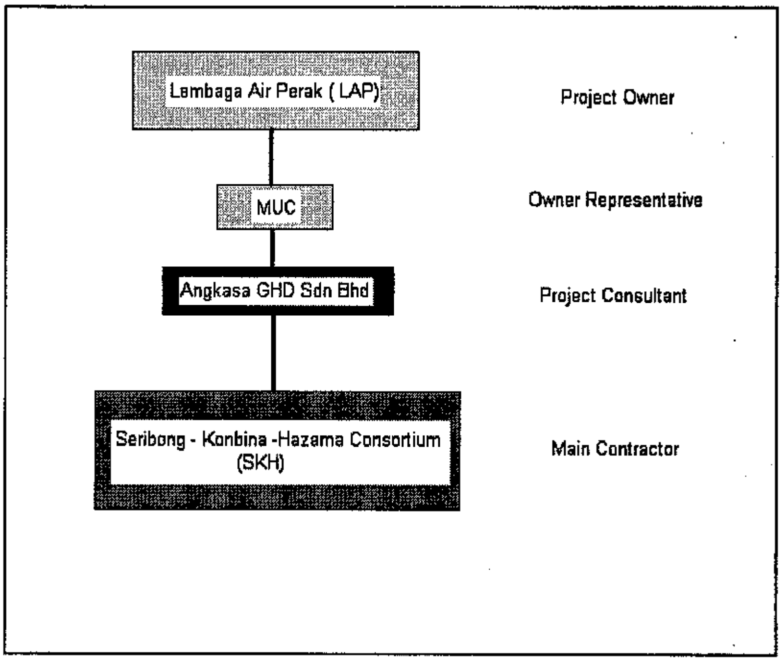


Figure 3.2 - Project organization chart

Construction progress depends on many factors such as weather, production and rate of placement. Figure 13 conclude that it can be place up to 500m^3 of RCC per day, depends on the work shift and rate of placement. Mostly the placing rate is between 20 – 50 m^3/hr. For the time being, the construction is yet to begin the 24 hour placement work. When it begins, it will boost up the current work progress.

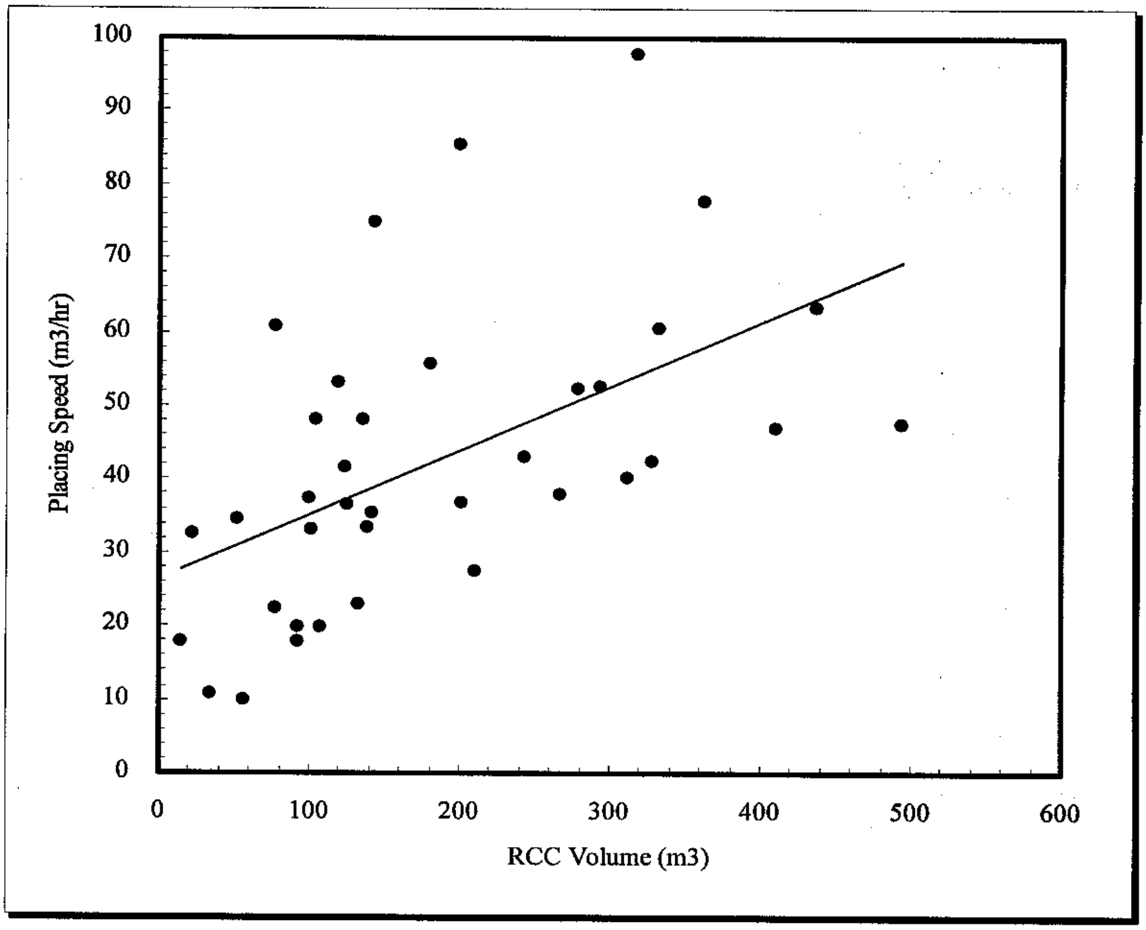


Figure 3.3 - Placing speed of RCC (m^3/hr)

Figure 3.3 and 3.4 below show the total RCC volume place up to date. But it is lagging behind the schedule, as it was planned to start on November 2003. But it just started in the middle of February 04 due to some arising matters.

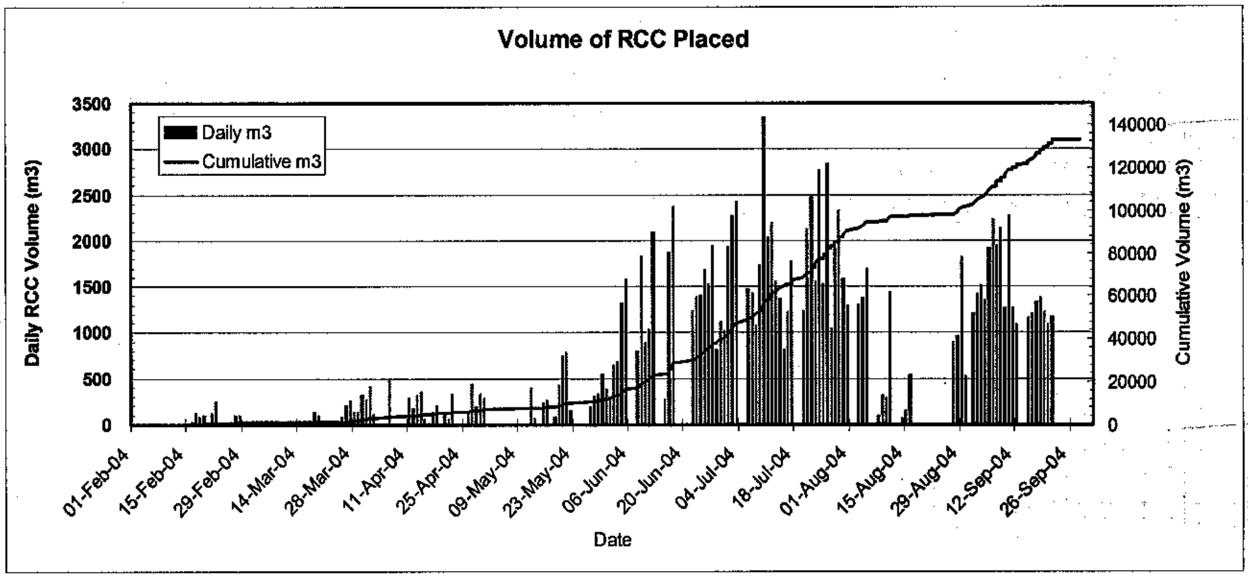


Figure 3.4 - Volume of RCC placed up to date

Difficulties in practical

The major problem is to deal with the weather and inconsistent climate. RCC cannot be placed during the raining period as it will give an impact in the moisture content of the layer. At least the RCC layer must be already compacted, so that the rain water will not seep below. The RCC layer is built with some degree of slope, so that any flow water can be directed to the drain. Construction progress will speed up as the monsoon season is over and after the placement work run 24 hours a with 2 shift of 12 hours each.

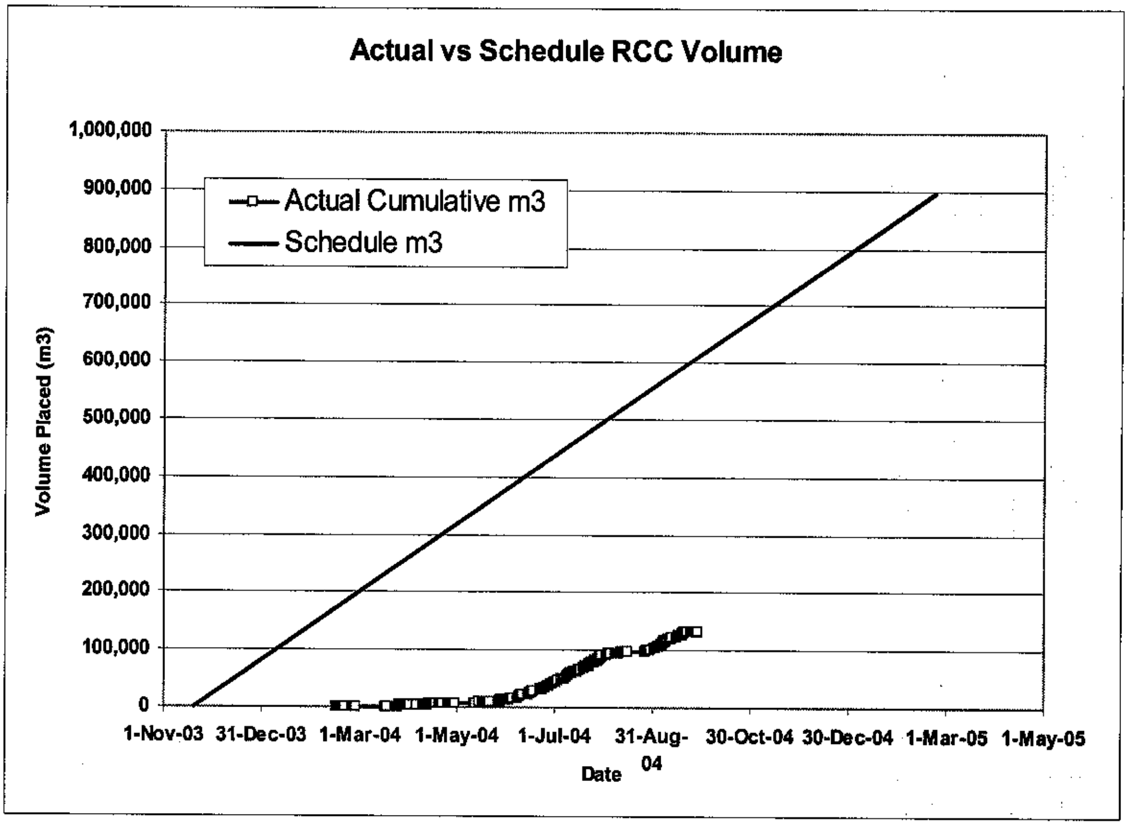


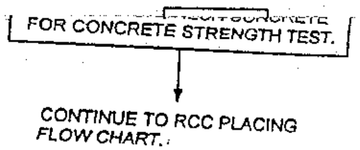
Figure 3.5 - Actual vs Schedule RCC Volume

The details of the Sg Kinta RCC Dam construction is attached in appendix 9.1 and 9.2

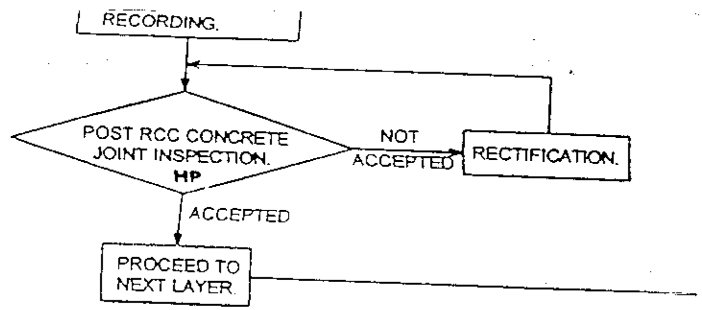
GREATER IPOH WATER SUPPLY SCHEME II
CONSTRUCTION OF SG. KINTA DAM AND ASSOCIATED WORKS

RCC WORKS FLOW CHART & ITP

RCC PRODUCTION



RCC PLACING



DATE	REVISION No.	APPROVED BY
30/01/04	3	T. Kan T. KAN

Table 3.1 - RCC Works Flow Chart

4 METHODOLOGY

The methodology for this project involved the following stages:

1) **Site Visit**

   This stage involved a visit to the site for a better understanding and view of the construction method, progress and technology applied.

2) **Review of reading material**

   A review of published paper and online resources as well as reference book is done during the study to enhance understanding on the RCC. The list of the material is attached at references.

3) **Experimental Works**
4) **Data Gathering**
5) **Stability Analysis**
6) **Compiling the project findings**

4.1 Site Visit

As the project require the student to observe the real construction progress, the student has been sent to Kenyir Dam and to study and overview the on going construction work of Sg. Kinta RCC dam for understand and experience the on site work. Although the Kenyir Dam is a Rock fill type dam, it is a useful visit as the student can have an review of the dam operation, maintenances and to see and understand all parts of the dam.

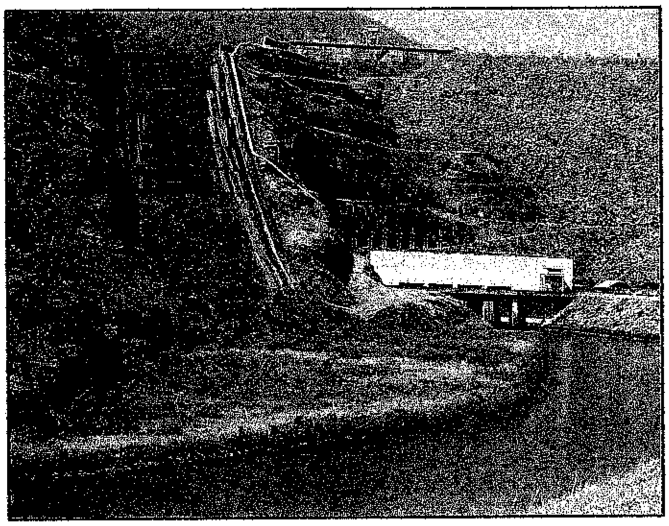


Figure 4.1 - Kenyir Dam from the downstream

The other site visit is to the Sg Kinta RCC dam in Ipoh. The purpose of the study is to get involves and experiences with RCC technology transformation from the others to the local. This including witnessing the construction progress, laboratory testing and RCC mixture proportion interpolation. To date, a total of 5 visits have been made since 28th February 2004. Since then, the student has been able to involve and follow up to the recent work progress. (*More pictures of the Sg Kinta Dam Project construction is attached in Appendix 9.2)*

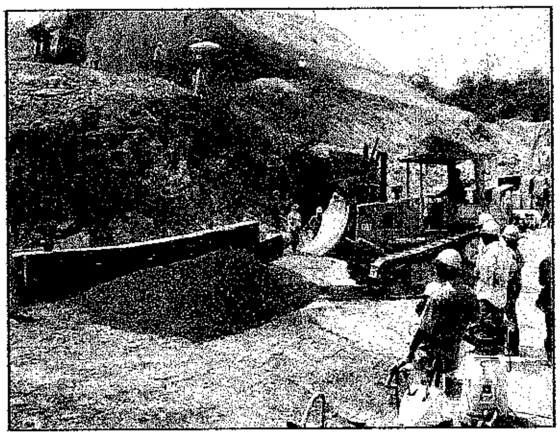


Figure 4.2 - Placement of RCC on site

5.1.2 CONCRETE DRUM MIXER

The efficient mixing of concrete prior to moulding specimens in the laboratory for subsequent testing is essential if quality specimens a re to be manufactured. The objective of mixing is to coat the surface of all aggregates particle with cement paste, and bring the mix to a uniform condition. Pan or rotating drum mixers are suitable for the mixing of small quantities of concrete which are generally used in a laboratory.

The drum mixer specification are model ELE34-3530 with 60 liter capacity. It is weight about 245 kg. It uses 220-240V with 50 Hz electrical supply.

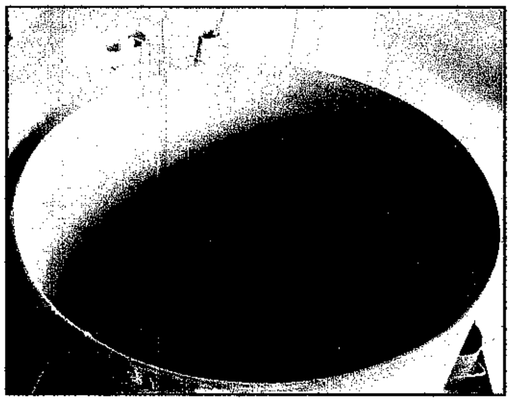


Figure 5.1 - Mixing Drum

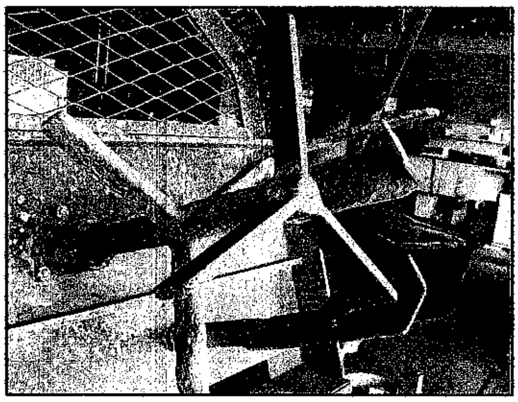
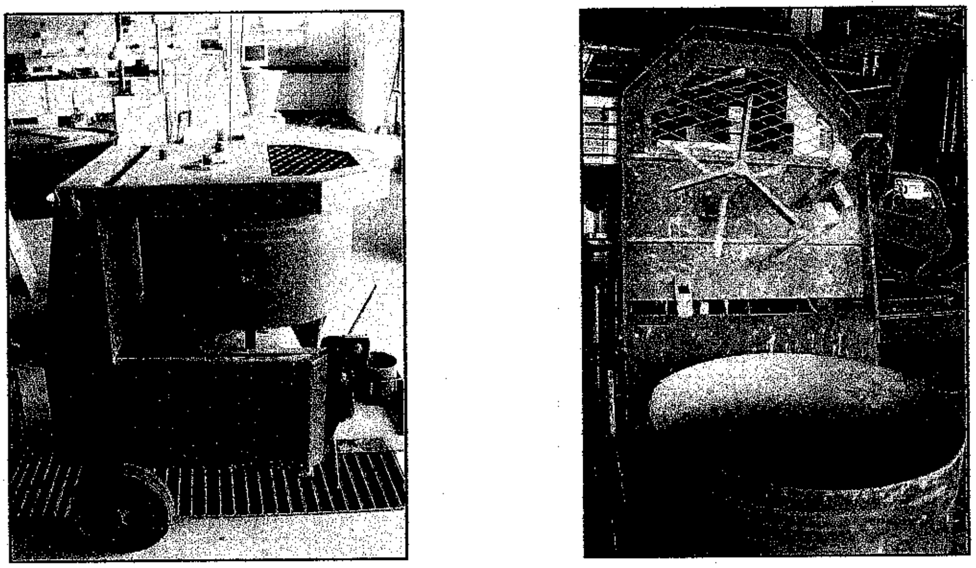


Figure 5.2 - .Mixer Paddle



(a) (b)

Figure 5.3 - Drum mixer side and front view

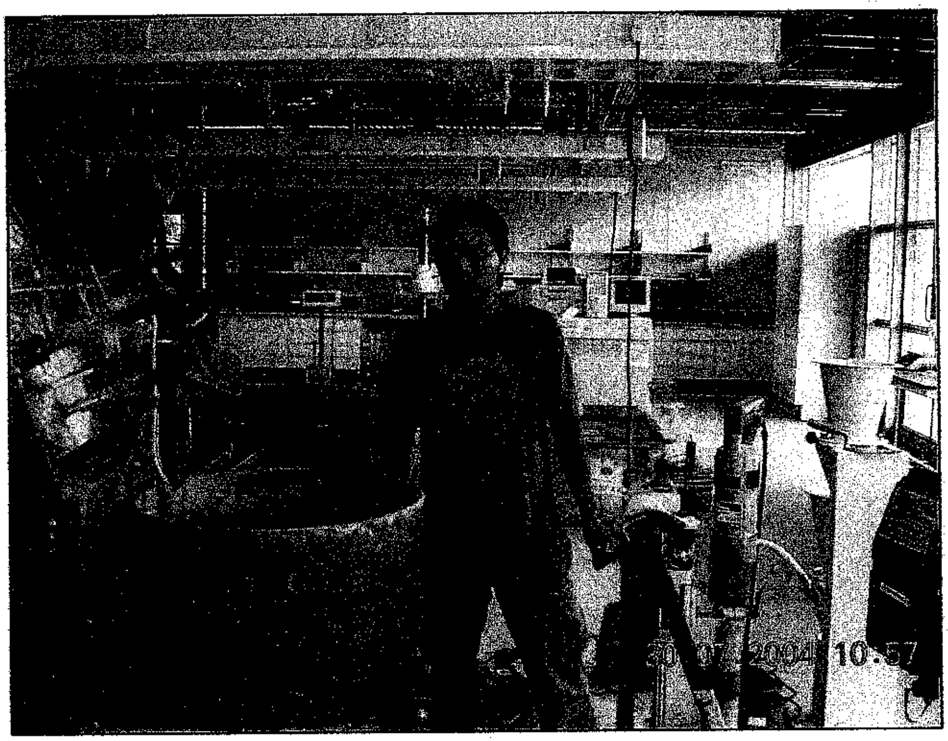


Figure 5.4 - Mixing a concrete with drum mixer

Discussion

This mixer is able to mixing fresh concrete for laboratory test samples. The mixing pan should be removable and tilts for easy access to the pan and emptying on completion of the mixing operation. Mixer should be rotated by turn table driven by a 1500W. The blades supply should be readily adjusted to suit the different types and volume of materials to be mixed. Pan supplied should be minimum capacity 56 liter. Mixer should be operated with 220-240V, 50 Hz at 1 phase. Some inconsistencies due to mixer characteristic contribute to the sampling failure.

5.1.2 SPLIT CYLINDER TEST PLATENS

This is split cylinder platens assembly (EL37-5420). The purpose of the platens is for testing cylinders of 150 x 300 mm (diameter & length). It is weight about 10.5 kg. There are clamps at side of the platen to hold the sample properly. It is used to carry out traction test by clearance on a cylindrical specimen, 150 x 300 mm (diameter & length). It is normally use with 1 compression machine

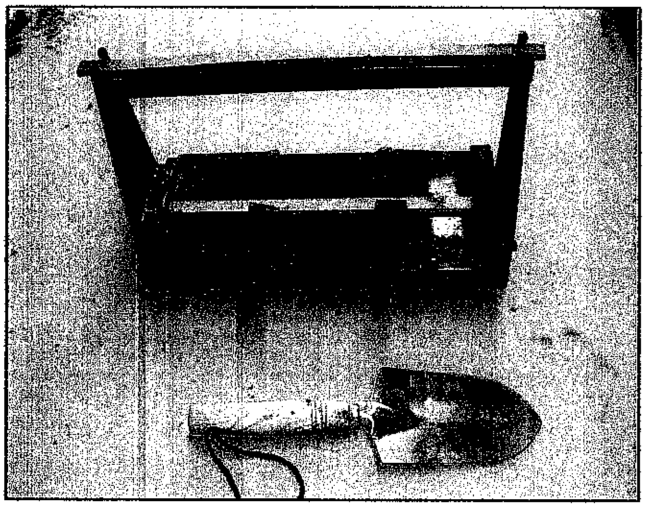


Figure 5.5 - Test Platens for split tensile test

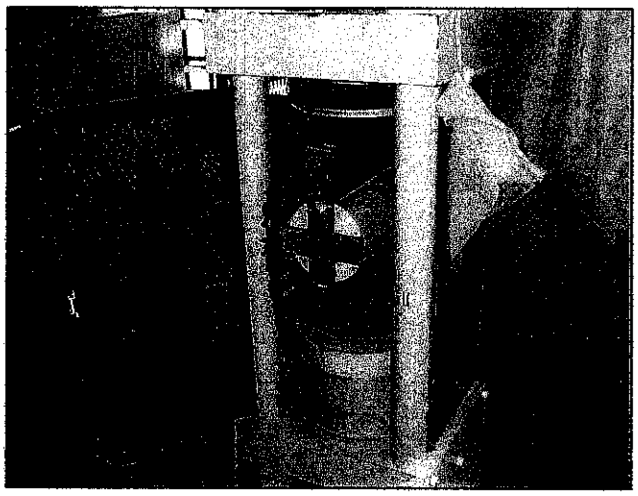


Figure 5.6 - Running the Split Tensile Strength Testing

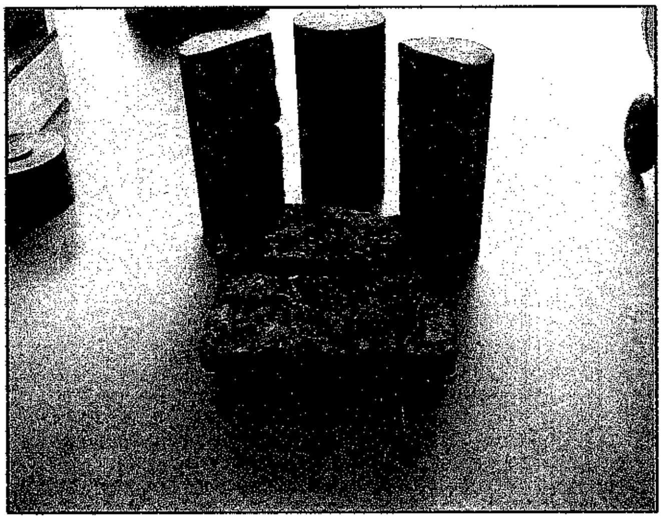


Figure 5.7 -Split sample after tensile test

5.1.3 1500 KN COMPRESSION MACHINE

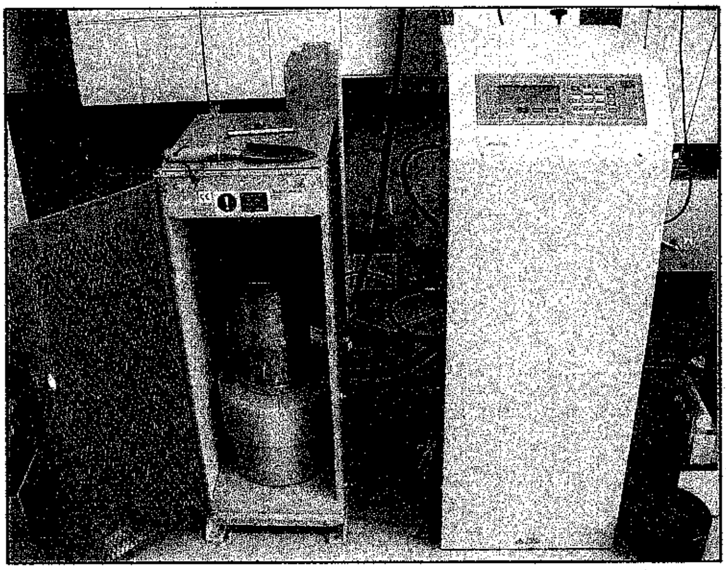
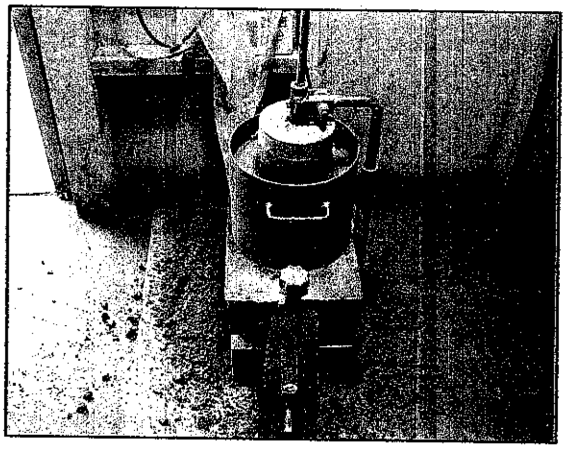


Figure 5.8 - Compression Machine

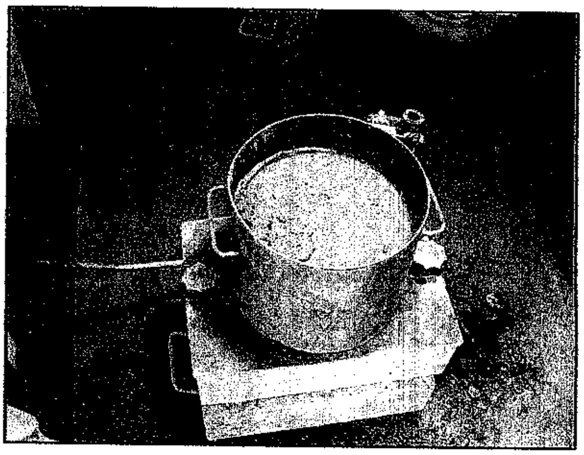
The compression machine is model compact ADR 1500. It is weight about 470 kg. It uses 220-240V with 50 Hz electrical supply. It uses 1350W power. This machine able for manual over ride for operator control Test result can be viewed and stores up to 200 tests before requiring down loading to computer and print out results. It is able to accommodate selections of sample type and size. It should be auto release when sample failure.

5.1.4 VEBE APPARATUS

Test appropriate for concrete mixes of low and very low workability of concrete. This method is a mechanized variation of the slump test and includes a determination of the concrete workability. It is based on the principle of subjecting the concrete to vibration after removal the slump cone. The time to complete the required vibration gives an indication to the concrete workability. Small vibrating table operated at fixed amplitude and frequency, and the plastic disc is placed contacted with upper surface of the concrete. Overall dimension of the table is 700x260x380mm (HxWxD). The consistometer must be operated from an electrical supply of 50 Hz in order to comply with the fixed test frequency specified.



(a)



(b)

Figure 5.9 - Vebe test to determine the time (12-27sec for RCC)

5.1.5 COMPACTOR

5.1.5.1 PLATE COMPACTOR

The main purpose of this machine is for compacting a soil, grass and a bituminous pavement for a small and also for area that could not be access by normal compactor. The compactor plate size is 521x432 mm. It is weight about 86 kg. It uses gasoline, with 4 strokes engine with 5 HP/3750 W power. The centrifugal force is 1550 KGF. The vibrating frequency is 6100 vpm.

Figure 5.10 - Plate Compactor

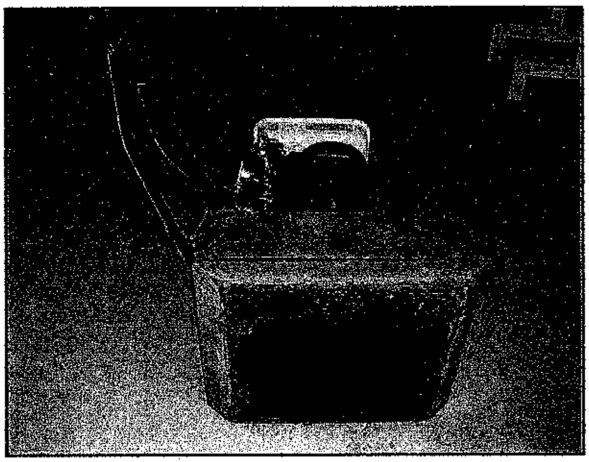


Figure 5.11 - Compactor Plate Surface

5.1.5.2 LIGHT HAND COMPACTOR (RECTANGULAR PLATE)

The main purpose is compacting a Conventional Concrete (CC) sample in beam or cube mould. It is also useful in producing a good surface finishing for any size of concrete mould. This compactor works well only with a high slump concrete like CC, but not with RCC due to the low compaction strength.

Figure 5.12 - Hand compactor

5.1.5.3 HEAVY HAND COMPACTOR (ROUND PLATE)

Figure 5.13 - Heavy Hand Compactor as compare to the light compactor

The heavy duty compactor use 220-240V with 50 Hz electrical supply. It consumes 800W power and the output is 3000 bpm. Here, it is only to be used with 150mm diameter mould as the plate diameter is 150mm too. This machine is heavy, and to it needs two people operate it efficiently.

5.1.6 CORING MACHINE

The purpose of this machine is for coring concrete sample (cube, cylinder etc) for further investigation. The core sample can be used to examine porosity, density, moisture content and also to examine the physical characteristic of the sample. It has a industrial diamond cutter at the bit to ensure a sharp and accurate cutting. It is very reliable as it can cut even hard granite aggregate. To use it properly, it need a continuous water supply as a cutting lubricant to avoid overheat and also to carry cutting debris.

Figure 5.14 - Coring the concrete sample

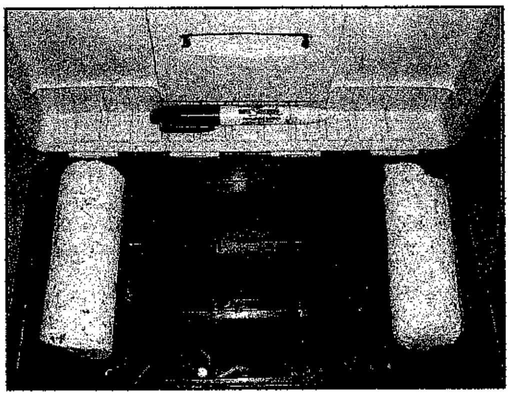


Figure 5.15 - RCC and CC core samples

5.1.7 POKER VIBRATOR

The main purpose is to reduce air voids in the mould by applying a vibration onto a slump/fresh concrete. But do not use it for a long time as it will make finer material and water move upward. It uses 220-240V with 50 Hz electrical supply. It consumes 550W power and the output is up to 3000 vpm.

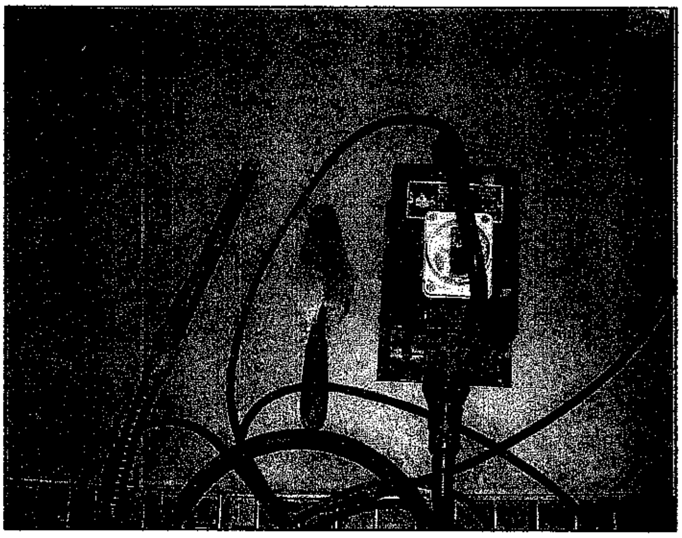


Figure 5.16 - Poker Vibrator

5.2 Tests on RCC

5.2.2 RCC mix design

Mix comparison of Roller Compacted Concrete (RCC) & Conventional Vibratory Concrete (CC) is as below:

Table 5.1 - Example of RCC and CC Mixture Proportion

amount	RCC	CC
density (kg/ m^3)	2440	2400
cement	90	351.36
fly ash	90	-
G1	295.99	-
G2	423.28	616.19
G3	507.94	616.19
sand	852.8	808.02
water content	45	176

**The calculation above is based on the 1 m^3 of the sample. For the Conventional Concrete, the calculation is based on normal concrete proportion and the w/c ratio is 0.5.*

5.1.3 <u>RCC CYLINDER</u>

- Compressive strength (1, 7, 28, 56, 90 days) – 3 cylinders each test
- Tensile strength (28, 56, 90 days) – 3 cylinders each test

Table 5.2 - RCC mix design for the first sampling

amount (kg)	RCC	total volume use=0.1145 m^3 @ 0.13 m^3	volume per mould (24 cylinders)	(3 cylinders)
weight (kg/ m^3)	2440	317.2	13.22	39.65
cement	90	11.7	0.49	1.46
fly ash	90	11.7	0.49	1.46
G1	295.99	38.48	1.60	4.81
G2	423.28	55.03	2.29	6.88
G3	507.94	66.03	2.75	8.25
sand	852.8	110.86	4.62	13.86
water content	45	5.85	0.24	0.73

5.1.3.1 Sample preparation.

.The main problems of RCC are:

1. Difficulty to obtain G1 aggregates or more known as grade 40 crusher. The student wants a total of less than 1 ton. But at the normal market, the minimum amount for purchase is 5 tons, according to the Papan Granite Sdn Bhd quarry. The price is only about RM 11/ton. As a temporary solution, the student gets some stock from the contractors working around the UTP.
2. At the moment, there are many FYP students and Concrete Technology student are using concrete laboratory. Some equipment are limited for the students such as machinery, mould and curing tank spaces.
3. After calculate and run the RCC sample, the students found that for the RCC layer project, it will be too much if it is going to mix $0.8m^3$ of RCC. Some modification should be made to solve this problem. The RCC layers will start after completing the RCC cylinder samples.

5.1.3.2 Problems

1. For the first RCC sample, it was found that half (3 out of 6) of the samples mixed are not physically good. Voids occur especially at the bottom of the cylinder. As this is the first batch of the RCC mix, it can be improved in the next mix will be made more carefully. The reason of the problem may be due to the:
   a. **Compactor** used is not strong enough to compact the RCC mix. At the site laboratory, they use a different type of compactor, which may have better compacting capability. This matter will be solved by using a better compactor.
   b. **Distribution of aggregates** is another thing that should be given more attention. Technique of placing the fresh concrete should be improved.

The unsuccessful samples are still cured and will be tested as usual. But the replacement sample will be made shortly. Next, after a few sampling is failed, the student decided to try to another mix design, which is a different mix of RCC. Later it produce a better RCC sample with the same compactor. So for the rest of the experiment, this mix is being used for both cylinder sample and RCC layers model. The main difference is the fly ash and cement content and also the water content, which is higher from the first mix. The first mix is the trial mix for the Sg Kinta Dam. From time to time, they will adjust the mix to comply with their standard and requirements. The second RCC mix is as below.

Table 5.3 - .RCC mix design for the second sampling

amount per m^3	RCC	total volume use = 0.1145 m^3 @ 0.13 m^3	volume per mould (24 cylinders)	Each Mix (3 cylinders)
weight (kg/m3)	2556.5	332.35	13.85	41.54
cement	72.1	9.373	0.39	1.17
fly ash	34.4	4.472	0.19	0.56
G1	624	81.12	3.38	10.14
G2	404	52.52	2.19	6.57
G3	524	68.12	2.84	8.52
sand	791	102.83	4.28	12.85
water content	107	13.91	0.58	1.74

The procedures of mixing the RCC sample are as below

Objective

To cast and cure test cylinders of a given RCC mix.

Apparatus

150 x 300 mm size of steel mould for test cylinders, A KANGO heavy compactor, water spray, light hand compactor for finishing.

Summary of Procedure

The quantity of cement, sand and course aggregate was weighed. Then make sure the material and machine is properly prepared. Brush the inner faces of moulds with grease oil and tighten the screws. Next Fill the mould with concrete sample in layers of 100mm deep approximately. Later compact each layer with the round face steel plate compactor 10 seconds for each layer. Apply water spray for each layer before and after the compaction to improve the joint properties of each layer.

Next, Repeat the placement of the RCC and repeat the compaction work too as above until the third layer. Using a nail mark the top surface of the concrete test cubes to indicate number and date of casting. After that, cover the moulds with polyethylene sheet or damp cloth to prevent evaporation and keep in the curing room for 24 hours. After 24 hours the concrete specimen should be removed from the moulds and stored in the curing tank until they are to be tested at a temperature of 25°C to 5°C. The preferred ages for test are 1, 7, 28, 56 and 90 days for the RCC samples. At least 3 specimens are made for each mix. The total samples made for RCC is 24 cylinders, for both compressive and tensile strength test.

Precaution

1. The fresh concrete samples should be tested for workability before casting. For the RCC, the best method is the Vebe Time Testing.
2. The specimen in the mould should not be moved within the first few hours after casting as this may lead to segregation and excessive bleeding of the concrete.

During the last visit to the Sg Kinta RCC Dam Site on 23rd October 2004, the student was given the latest design mix as used in the RCC dam construction. The water content is higher and the fly ash – cement content is also higher. The mix design is as below:

Table 5.4 - RCC mix design for the latest placement (30 Aug 04)

Amount (Kg)	RCC
Weight (Kg/ m^3)	2435
Cement	100
Fly Ash	100
G1	229
G2	459
G3	551
Mining Sand	236
Quarry Sand	550
AE Reducer	0.4
Water Content	145

Based on the current mix design, it is totally different to the RCC sample mix by the student. This is the main factor that contribute to the differences in the strength test perform on both mix. However, that will be discussed in the next part of this chapter.

5.2.3 Compressive Strength

Objective

To determine the compressive strength (crushing strength) of concrete according to BS 1881: Part 116: 1983.

Theory

One of the most important properties of concrete is its strength in compression. The strength in compression has a definite relationship with all other properties of concrete. The other properties are improved with the improvement in compressive strength. The compressive strength is taken as the maximum compressive load it a per unit area.

Apparatus

A compression machine testing capacity of 1500KN

Summary of Procedure

Firstly, remove the test cylinder from the curing tank and wipe off surface water with a damp cloth. Weigh the cylinder to the nearest kg. Place the cylinder centrally on the lower platen of the test machine with the rough top surface of the test cube facing towards you. Next, Lower the top platen onto the cylinder and ensure a uniform setting by gently rotating the top platen as it is brought to bear on the cube. Then, Make sure that the test machine is set to the correct loading and pointers are set at zeroes. Apply the load without shock and continuously increase at a rate of 2.10 MPa/s until no greater load can be sustained by the test cube. Finally, record the maximum load carried by each specimen during test and note the type of failure and appearance of cracks

The results are as below:

Table 5.5 - .RCC Compressive strength result

Test	Sample	Load (KN/Mm^2)	Stress (Mpa)
1 D COMP	1	37.40	2.12
	2	30.10	1.70
	3	33.30	1.89
Average		**33.60**	**1.90**

(a).1 day

Test	Sample	Load (KN/Mm^2)	Stress (Mpa)
7 D COMP	1	52.50	2.97
	2	50.80	2.87
	3	44.50	2.52
Average		**49.27**	**2.79**

(b).7 days

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
28 D COMP	1	67.8	3.84
	2	78.3	4.43
	3	68.8	3.89
Average		**71.63**	**4.05**

(c).28 days

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
56 D COMP	1	113	6.395
	2	128.2	7.26
	3	129.6	7.333
Average		**123.60**	**7.00**

(d).56 days

Test	sample	load (kN/mm2)	stress (MPa)	remarks
90 d	1	481.7	27.26	
	2	109.4	6.191	rejected as unrealistic
	3	152.8	8.647	rejected as unrealistic
average		**481.7**	**27.26**	

(d).90 days

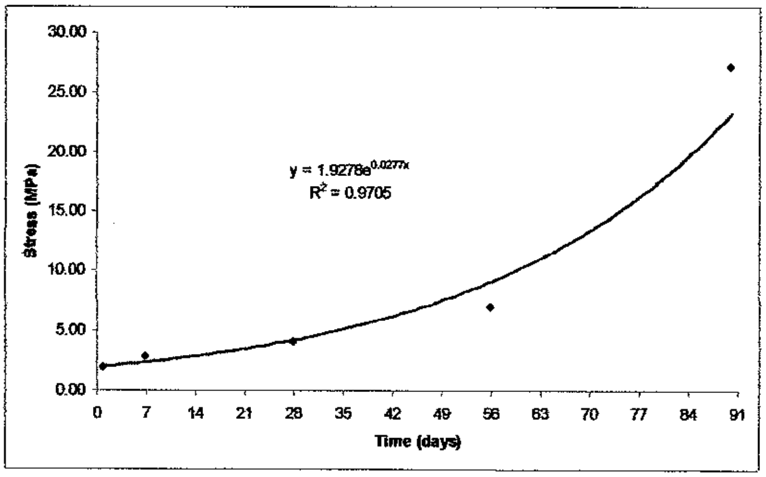


Figure 5.17 - RCC compressive strength up to 90 days

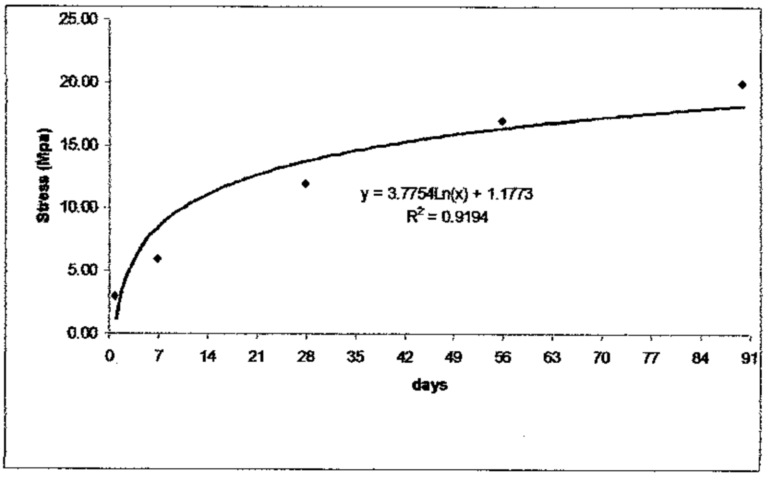


Figure 5.18 - RCC theoretical compressive strength

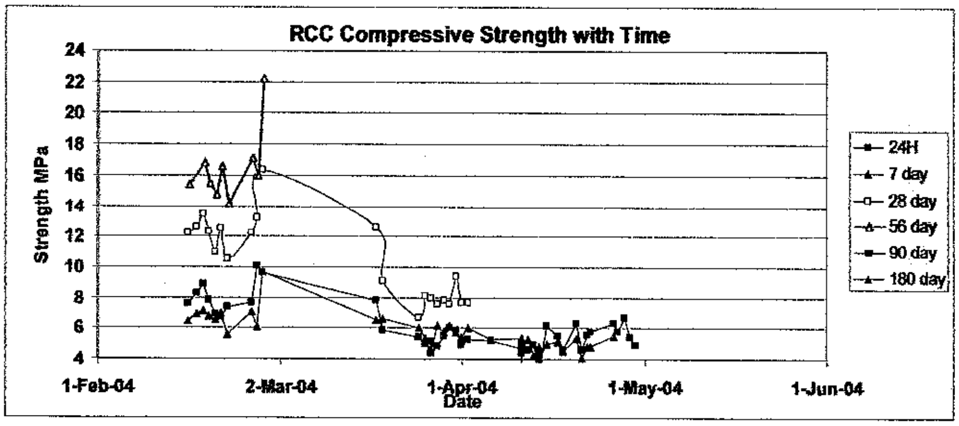


Figure 5.19 - .RCC compressive strength of Sg Kinta Dam

5.2.4 Tensile Strength

Objective

To determine the split tensile strength of concrete according to BS 1881.

Theory

One of the most important properties of concrete is its strength in tensile. The strength in tensile has a definite relationship with all other properties of concrete. The other properties are improved with the improvement in tensile strength.

Apparatus

A compression machine testing capacity of 1500KN

Summary of Procedure

First remove the test cylinder from the curing tank and wipe off surface water with a damp cloth. Next weigh the cylinder to the nearest kg. Place the cylinder fix to the tensile platen and place it horizontally to the compression machine. Make sure that the test machine is set to the correct loading and pointers are set at zeroes. Apply the load without shock and continuously increase at a rate of 0.7 MPa/s until no greater load can be sustained by the test cube. Record the maximum load carried by each specimen during test. Note the type of failure and appearance of cracks

The results are as below:

Table 5.6 - RCC Split Tensile Strength results

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
28 D TENSILE	1	46.00	0.65
	2	43.10	0.61
Average		**44.55**	**0.63**

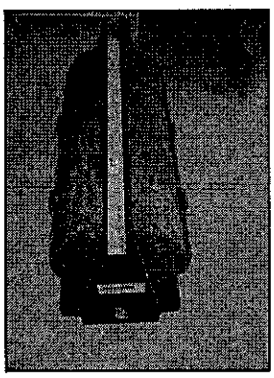
(c).28 days

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
56 D TENSILE	1	61.00	0.86
	2	55.40	0.78
	3	63.20	0.89
Average		**59.87**	**0.85**

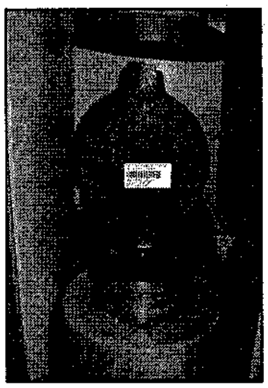
(d).56 days

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
90 D TENSILE	1	78.30	1.11
	2	95.4	1.35
	3	92.7	1.31
Average		**88.8**	**1.26**

(d).90 days



(a)



(b)

Figure 5.20 - Split tensile test by using compression machine

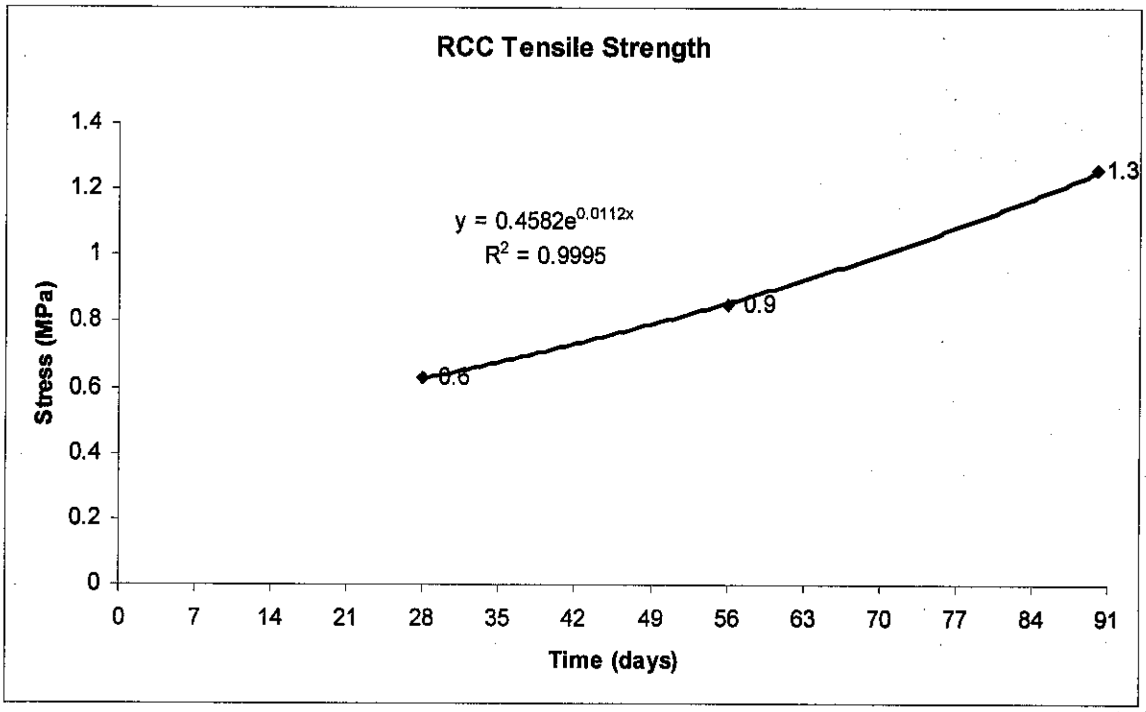


Figure 5.21 - RCC tensile strength up to 90 days

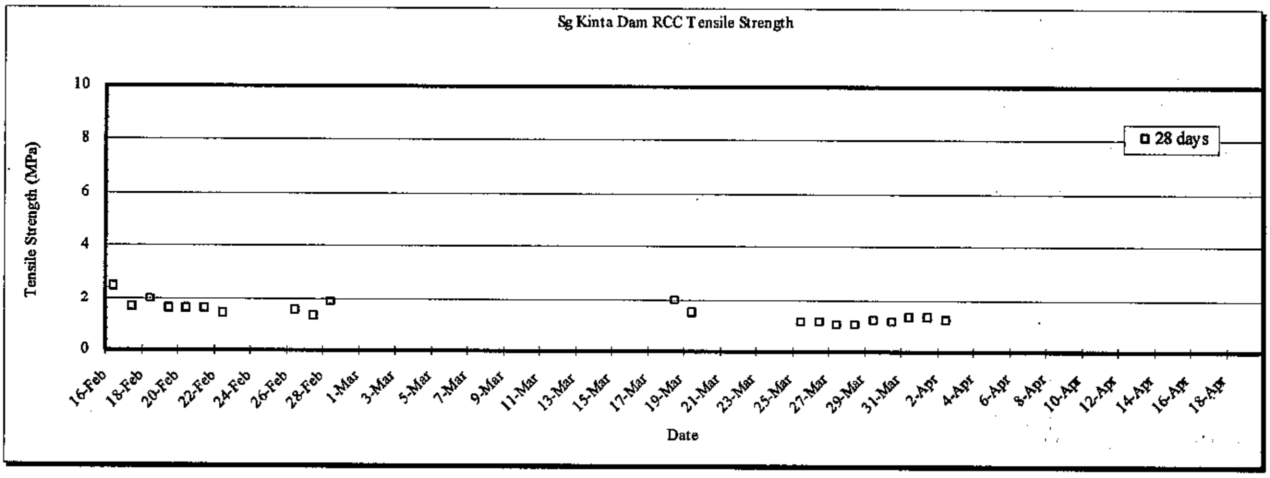


Figure 5.22 - Sg Kinta Dam RCC tensile strength

5.3 Bedding Mortar

5.3.2 Bedding Mortar mix design

Bedding mortar purpose is to be placed between two RCC layers. It will act as a adhesive between these layers and improve the joint properties between the layers. The experiment will be done to ensure that the bedding mortar made is up to the requirement. Theoretically, it should be perform greater performances than RCC.

The mortar mix is as below:

Table 5.7 - Mortar mix design for RCC joint placement

	Mortar
Amount (Kg)	2
Cement	0.5 kg
Sand	1.5 kg
Water Content	0.25 kg

Summary of mixing procedure

First, weight the sand, cement and water according to the correct proportion. Next, mix them uniformly and immediately, place them on the RCC layers by spreading at 5 mm thickness.

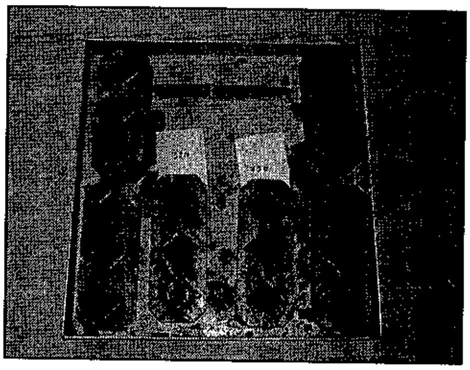


Figure 5.23 - Preparation of mortar samples

5.3.3 Compressive Strength

For mortar, only compressive strength test (7, 14 and 28 days) is done. The results are as below.

Table 5.8 - Mortar compressive strength

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
7 COMP	1	27.40	10.97
	2	25.00	10.00
	3	13.70	5.48
		22.03	**8.82**

(a).7 days

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
14 COMP	1	39.6	15.85
	2	37.7	15.08
	3	35.9	14.34
		37.73	**15.09**

(b).14 days

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
28 COMP	1	42.5	17.01
	2	45.7	18.28
	3	44.3	17.72
		44.17	**17.67**

(c).28 days

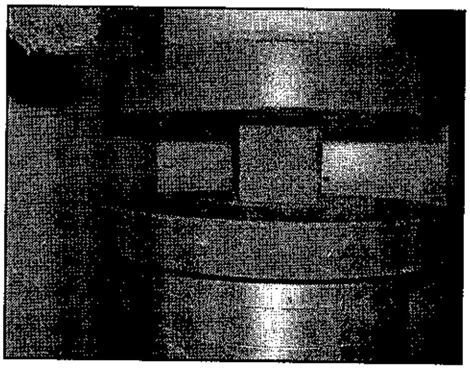


Figure 5.24 - Mortar cube compressive strength test

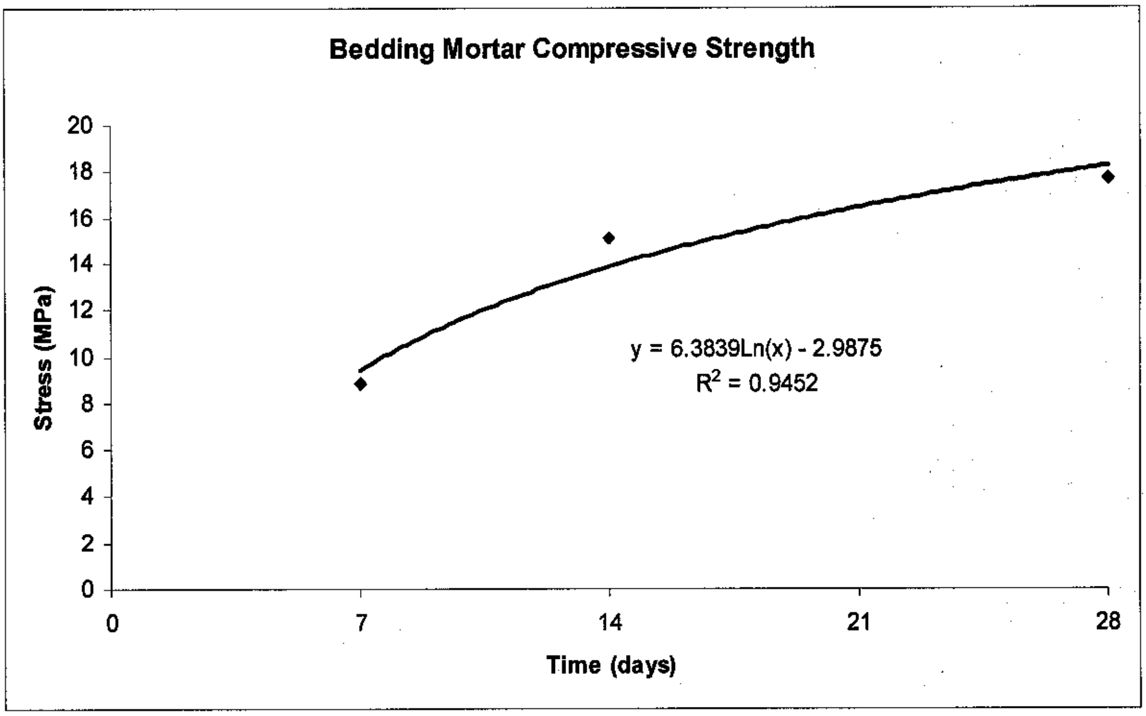


Figure 5.25 - Bedding Mortar compressive strength

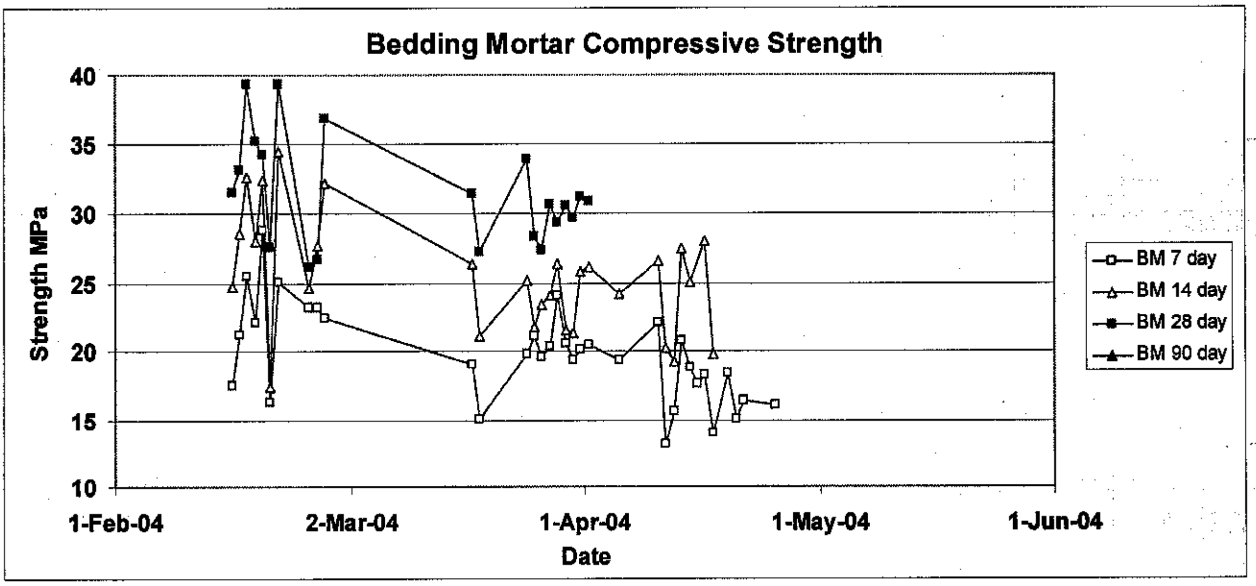


Figure 5.26 - Sg Kinta Dam bedding mortar compressive strength

5.4 Tests on Conventional Concrete

5.4.2 CC mix design

The CC samples are required for the test as below:

- Compressive strength (1, 7, 28, 56, 90 days) – 3 cylinders each
- Tensile strength (28, 56, 90 days) – 3 cylinders each

The material used for Conventional Concrete (CC) is as below:

Table 5.9 - CC mix design for the control

amount (kg)	CVC	total volume use=0.1145 m^3 @ 0.13 m^3	volume per mould (24 cylinders)	(3 cylinders)
weight (kg/ m^3)	2400	312	13	39
cement	351.36	45.68	1.90	5.71
fly ash				
G1				
G2	616.19	80.10	3.34	10.01
G3	616.19	80.10	3.34	10.01
sand	808.02	105.04	4.38	13.13
water content	176.00	22.88	0.95	2.86

Note: Cylinder 6' X 12' (0.1524 m X 0.3048m)

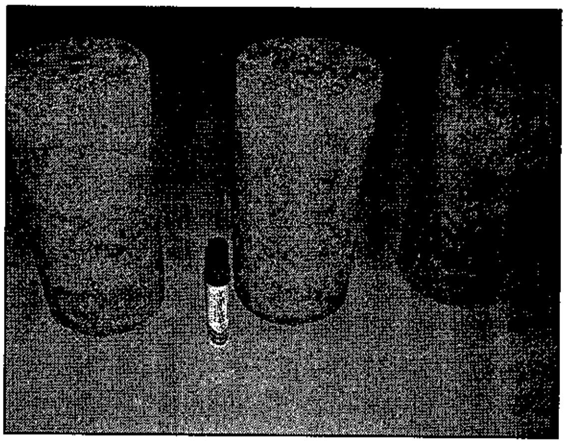


Figure 5.27 - CC cylinder samples

The procedures of mixing the CC sample are as below

Objective

To cast and cure test cylinders of a given CC mix.

Apparatus

150 x 300 mm size of steel mould for test cylinders, light hand compactor for finishing.

Procedure

The quantity of cement, sand and course aggregate was weighed according to the designed mix. Ensure that the machine and materials used are properly prepared. Brush the inner faces of moulds with grease oil and tighten the screws. Fill the mould with concrete sample in layers of 100mm deep approximately. Next, apply pocket vibrator inside the mould to release air bubbles and make it uniform inside.. Repeat the placement of the CC and repeat the vibratory work too as above until the third layer.. Using a nail mark the top surface of the concrete test cubes to indicate number and date of casting.

Cover the moulds with polyethylene sheet or damp cloth to prevent evaporation and keep in the curing room for 24 hours. At least after 24 hours the concrete specimen should be removed from the moulds and stored in the curing tank of 25°C to 5°C Preferred ages for test are 1, 7, 28, 56 and 90 days for the CC samples.. Noted that at least 3 specimens are made for each mix. The total samples made for RCC is 24 cylinders, for both compressive and tensile strength test.

Precaution

1. The fresh concrete samples should be tested for workability before casting. For the CC, the best method is the Slump Test.
2. The specimen in the mould should not be moved within the first few hours after casting as this may lead to segregation and excessive bleeding of the concrete.

5.4.3 Workability slump test

Objective

To measure the workability of a sample from a batch of fresh concrete

Theory

The measurement of the workability of fresh concrete is important in assessing the practicality of compacting the mix and also in maintaining consistency throughout the job. The slump test is very useful on site as a check of day-today or hour-to-hour variation in the material being fed into mixer. There are three types of slump:

i. True slump

ii. Shear slump

iii. Collapse

Apparatus

The apparatus consists of

- A truncated conical mould 100mm in diameter at the top, 200mm at bottom and 300mm high,
- A steel tamping rod (16mm diameter and 600mm long), rounded at one end,
- A scoop,
- A steel ruler and
- A steel trowel

Summary of Procedure

Clean the inside moulds and places it on a hard, flat and non absorbent surface. Take representative sample (about 15kg) from a fresh concrete. Fill the mould in four layers of concrete of approximately equal depth (each layer is about 75 mm). Each layer is rodded 25 times with the rounded end of the steel rod. Make sure each rodding passes through the each layer. After the top layer has been rodded, the surface of the concrete is struck off t to level up with the top of the mould.

Clean away any spillage of concrete around the base of the mould. Carefully and slowly lift the mould vertically from the concrete. Invert the mould and place it next to the molded concrete. The concrete will slump. Place the rod across the top of the mould. The slum is the difference between the height of the slumped concrete and the mould. Using the steel ruler, measure the slump from the top of the concrete to the underside of the rod. Record the slump to the nearest 5mm.

Result

Slump Test Result is as below:

Table 5.10 – Slump Test Result

Reading	(mm)
1	40

Discussion

Based on the result the slump is fall in the true slump category. This shows that the slump 4.0 cm have very low workability. The slump is suitable for roads vibrated by power-operated machines. Concrete may be compacted in certain cases with hand-operated machines. The slump 0 is suitable used for slab and other contraction. From the result we obtain then we can know that the concrete is suitable or not for the building construction or other purposes. Factors affecting workability are:

- Water content
- Aggregate type
- Grading
- Aggregate/cement ratio
- Presence of admixtures
- Fineness of cement

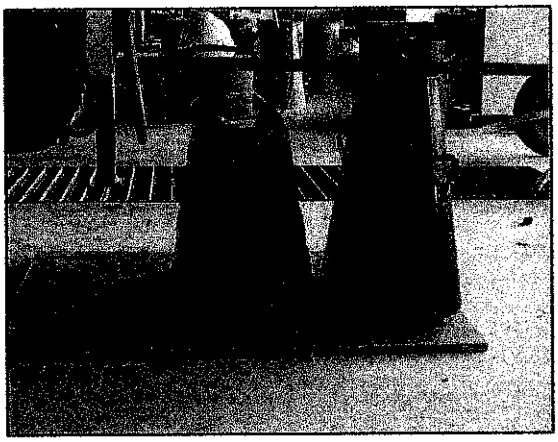


Figure 5.28 - CC workability slump test

5.4.4 Compressive strength

Objective

To determine the compressive strength (crushing strength) of concrete according to BS 1881: Part 116: 1983.

Theory

One of the most important properties of concrete is its strength in compression. The strength in compression has a definite relationship with all other properties of concrete. The other properties are improved with the improvement in compressive strength. The compressive strength is taken as the maximum compressive load it a per unit area.

Apparatus

A compression machine testing capacity of 1500KN

Procedure

Firstly, remove the test cylinder from the curing tank and wipe off surface water with a damp cloth. Weigh the cylinder to the nearest kg. Place the cylinder centrally on the lower platen of the test machine with the rough top surface of the test cube facing towards you. Next, Lower the top platen onto the cylinder and ensure a uniform setting by gently rotating the top platen as it is brought to bear on the cube. Then, Make sure that the test machine is set to the correct loading and pointers are set at zeroes. Apply the load without shock and continuously increase at a rate of 2.10 MPa/s until no greater load can be sustained by the test cube. Finally, record the maximum load carried by each specimen during test and note the type of failure and appearance of cracks

The results for the compressive test are as below:

Table 5.11 - CC compressive strength test

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
1 D COMP	1	204.60	11.58
	2	132.30	7.49
	3	94.30	5.33
Average		143.73	8.13

(a).1 day

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
7 D COMP	1	487.20	27.57
	2	297.30	16.82
	3	432.50	24.47
Average		405.67	22.95

(b).7 days

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
28D COMP	1	381.9	21.61
	2	389	22.02
	3	302.7	18.05
Average		357.87	20.56

(c).28 days

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
56D COMP	1	724.00	40.97
	2	452.80	25.63
	3	187.70	10.62
Average		**454.83**	**25.74**

(d)56 days

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
90D COMP	1	522.4	29.56
	2	531.3	30.07
	3	461.7	26.13
Average		**505.13**	**28.59**

(e). 90 days

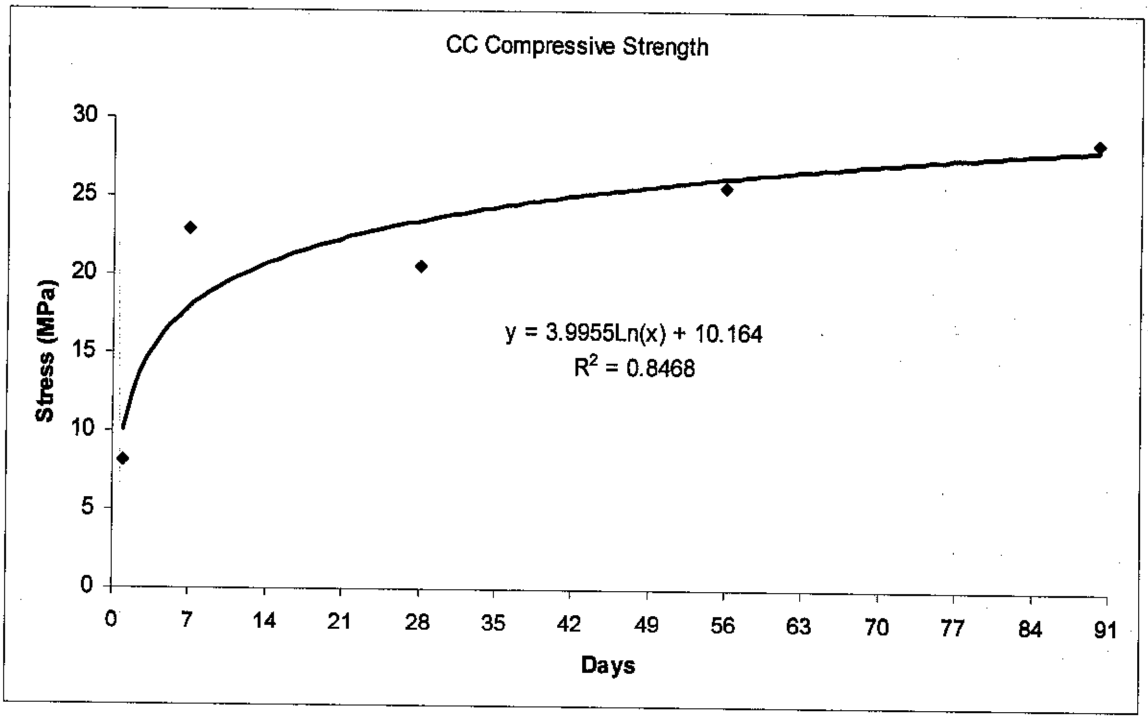


Figure 5.29 - CC Compressive Strength

Discussion

Base on graph above, the CC samples compressive strength is higher than the RCC sample. At the end of the 28 days, it has achieved a 20.56 MPa, which is normal for the CC. Theoretically, CC strength will increase rapidly from the beginning until the 28 days, and it will increase slightly after that period. This experiment has indicated that the results are within the theory. Due to some unknown errors, the 7 days strength has shown higher strength than the 28 days. 90 days strength is slightly higher with 28.59 MPa, which might be due to the continuous curing.

5.4.5 Tensile strength

Objective

To determine the split tensile strength of concrete according to BS 1881.

Theory

One of the most important properties of concrete is its strength in tensile. The strength in tensile has a definite relationship with all other properties of concrete. The other properties are improved with the improvement in tensile strength.

Apparatus

A compression machine testing capacity of 1500KN

Procedure

First remove the test cylinder from the curing tank and wipe off surface water with a damp cloth. Next weigh the cylinder to the nearest kg. Place the cylinder fix to the tensile platen and place it horizontally to the compression machine. Make sure that the test machine is set to the correct loading and pointers are set at zeroes. Apply the load without shock and continuously increase at a rate of 0.7 MPa/s until no greater load can be sustained by the test cube. Record the maximum load carried by each specimen during test. Note the type of failure and appearance of crack

Results

The results of the CC split tensile strength are as below:

Table 5.12 - CC tensile strength test

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
28 D TENSILE	1	190.40	2.69
	2	252.90	3.58
	3	247.00	3.50
Average		**230.10**	**3.26**

(a).28 days

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
56 D TENSILE	1	213.30	3.018
	2	222.10	3.142
	3	194.00	2.744
Average		**209.80**	**2.97**

(b) 56 days

Test	Sample	Load (KN/Mm^2)	Stress (MPa)
90 D TENSILE	1	223.20	3.158
	2	228.00	3.226
	3	232.80	3.293
Average		**228.00**	**3.23**

(c). 90 days

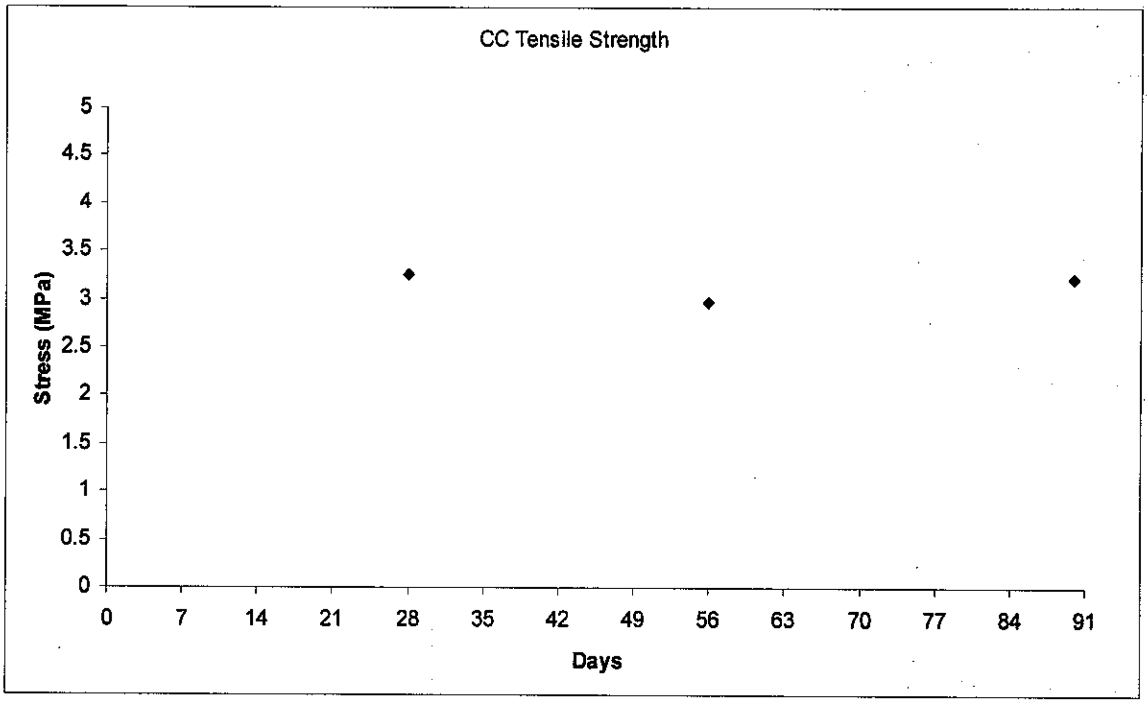


Figure 5.30 - CC Tensile Strength

Discussion

For the CC tensile strength, the test has been done according to the 28, 56 and 90 days as done with the RCC sample at the Sg Kinta Dam site. Here, there are not many changes since the day 28 to day 90. Theoretically, it will perform like that as for CC; there is not much change in the strength after the day 28.

5.5 Experience with RCC layers

The RCC layer will be build to understand, visualize and experience on how a l RCC dam is being built. The process will be done as in situ condition, except for the equipment, as it will be done by using a small type compactor. A total of two layers will be build. The layers will be done by using two type of different compactor in order to investigate and study the effect of both compactions. The dimension of the model is as below.

Volume of RCC = Thickness*Width*Length
= [0.3*0.5*1.2] m
= **$0.18m^3$**

Thickness = (150mm each) & 1 Bedding Mortar Layer (20mm)

The materials required to build the layers is as below:

Table 5.13 - RCC layers model mix design

amount per m^3	RCC	total volume use=0.18 m^3
weight (kg/ m^3)	2556.5	460.17
cement	72.1	12.98
fly ash	34.4	6.19
G1	624	112.32
G2	404	72.72
G3	524	94.32
sand	791	142.38
water content	107	19.26

Discussion

1. The problem with the RCC layer to be built is it requires an extensive amount of material and difficulty to mix. Laboratory mixer is limited to mix small volume of concrete at once. Some adjustment should be done to build it within scope of capability.

2. Although it is a layer, the student find that it still needs to build a formwork to make it compacted properly within the enclosed area. Simple formwork that can sustain load from the compactor will be made from wood.

3. Difficulty to obtain the roller compactor machine. UTP Concrete Lab does not have it. Most of the contractor does not provide a renting service for this machine.

Procedure

The RCC mix as the normal mixing procedure. For each layer, it is most suitable to do 4 mixing for the required RCC volume. It has to be 4 times mixing due to the limitation of the drum mixer volume. The first layer will be build by using a plate compactor. After finishing the first layer, it will be left dry for some times. Net a 20 mm thickness bedding mortar layer will be spread to the whole surface. Right after that, next RCC layer will be placed shortly. For the next layer, it will be compacted by using a 1 ton roller compactor.

Below are the RCC layers diagrams and picture.

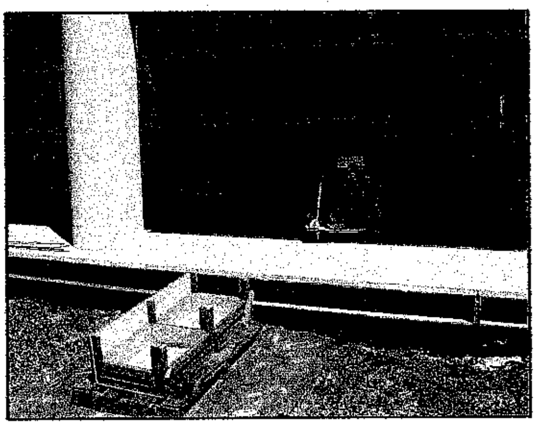


Figure 5.31 - RCC layers ready for placement

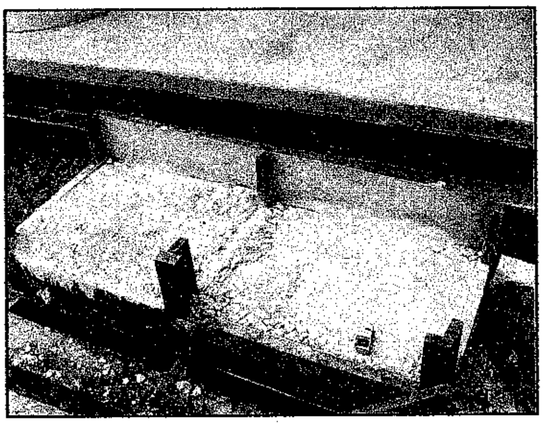


Figure 5.32 - RCC first layer 24 hours after compaction

Procedure

The RCC mix as the normal mixing procedure. For each layer, it is most suitable to do 4 mixing for the required RCC volume. It has to be 4 times mixing due to the limitation of the drum mixer volume. The first layer will be build by using a plate compactor. After finishing the first layer, it will be left dry for some times. Net a 20 mm thickness bedding mortar layer will be spread to the whole surface. Right after that, next RCC layer will be placed shortly. For the next layer, it will be compacted by using a 1 ton roller compactor.

Below are the RCC layers diagrams and picture.

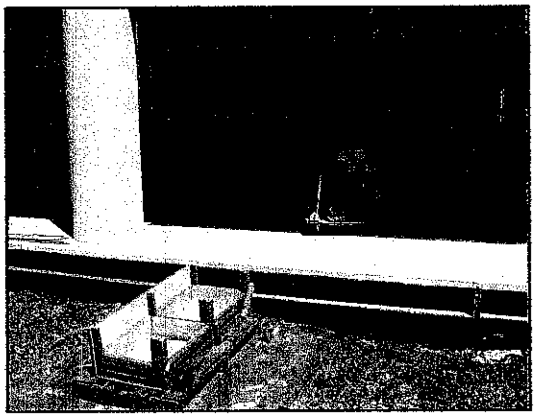


Figure 5.31 - RCC layers ready for placement

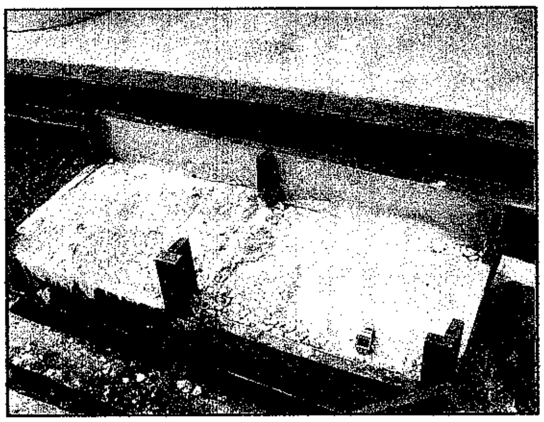


Figure 5.32 - RCC first layer 24 hours after compaction

5.6 Discussion on Experiments

Those experiments have shown that the Sg Kinta Dam RCC result is almost similar to the properties of CC, either in compressive or tensile strength. Thus it has proved that a quality RCC is achievable by using a less cementitious material and also at lower cost of mixing and operation. But for this study, the RCC sample mixed and tested properties, in term of strength is lower than the Sg Kinta Dam RCC. Most of the errors come from:

1. <u>*Drum Mixer inconsistencies*</u>: The mixer mixes the materials horizontally. Thus it does not mix uniformly as the finer material (sand, cement, and fly ash) will be pushed aside from the blade. The coarse material will stuck in the middle of the mixer. It has to be mix manually after some rotation.

2. <u>*Compaction*</u>: Type of compactor and also compaction number contribute to the sample failure. A reasonable number of compaction should be applied for the RCC sample.

3. <u>*Air Entrained agent*</u>: Retention of the air in the concrete is the mechanic entraining of the large and well distributed number of the minuscule air bubble during the moisture of the concrete, produced through the entraining of the appropriate air agent.
4. <u>*Type of sand*</u>: For all the experiment, the sand used is the river sand, as it is the only available resources here. But at the Sg Kinta Dam , the RCC is mix by using a mixture between a quarry sand and mining sand of 70:30 ratio. The reason is to improve the RCC mix design. The different sand type and sand moisture content may contribute to the samples error.

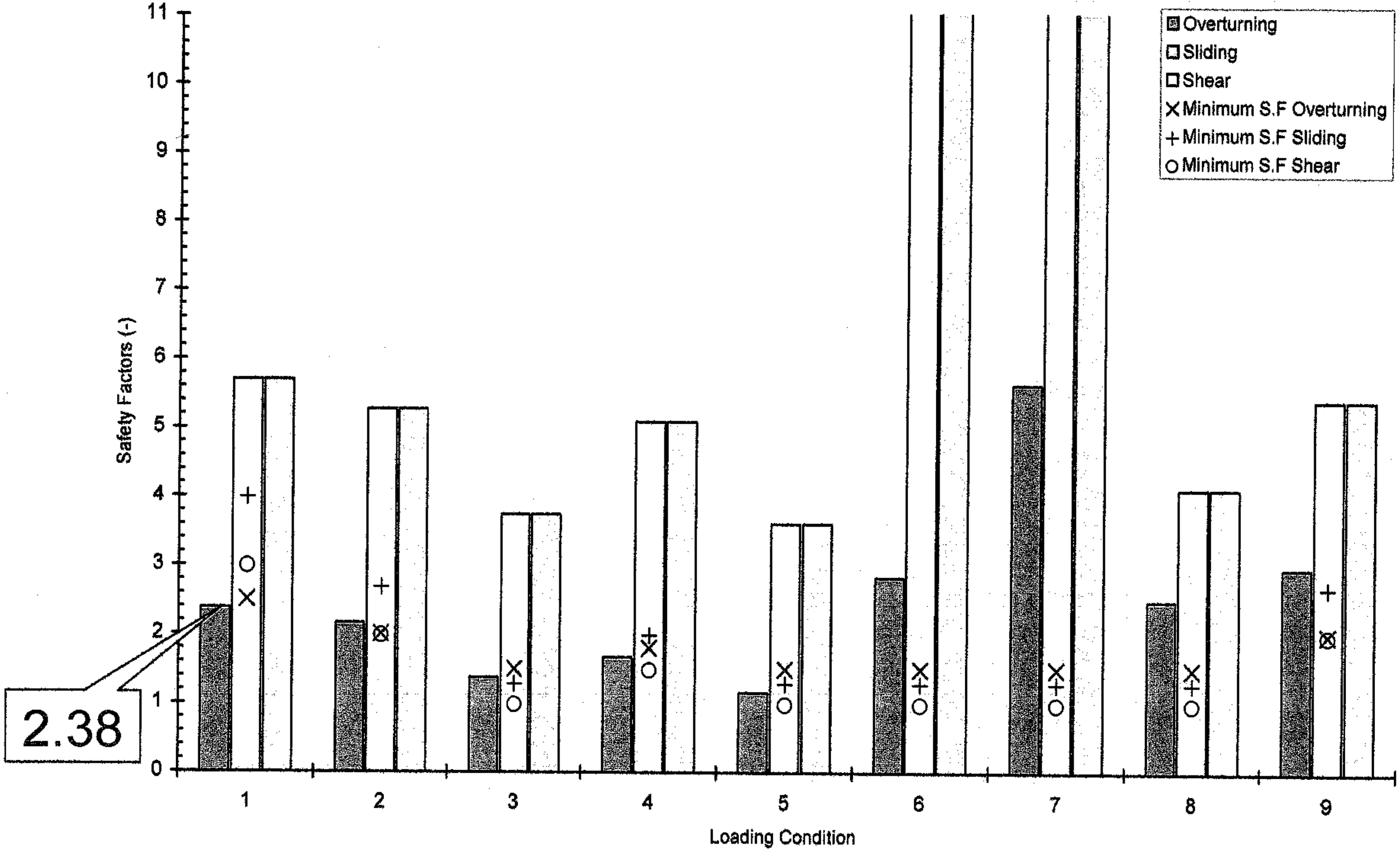


Figure 6.1 – GRACDAM analysis for loading condition 1

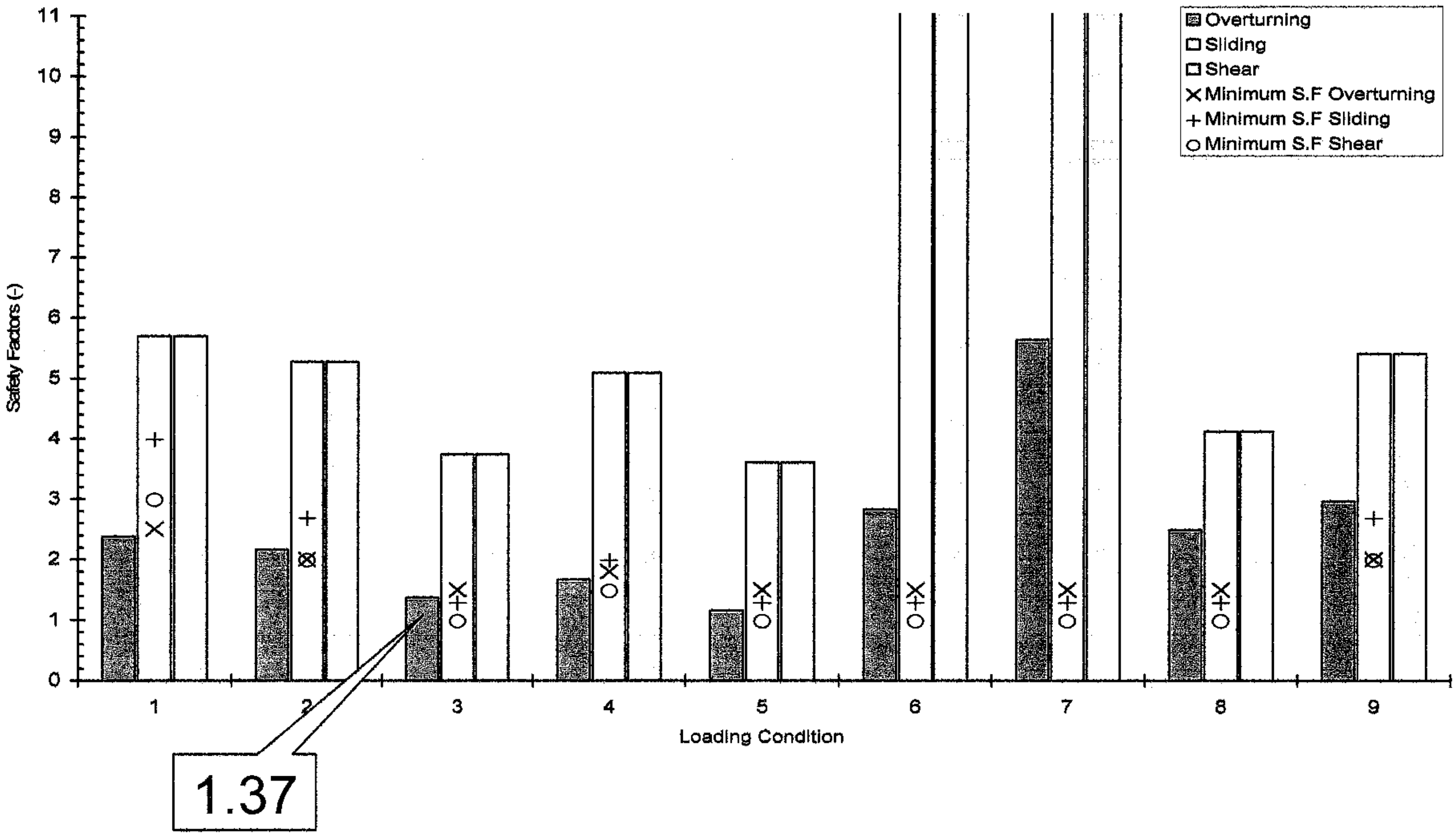


Figure 6.2 – GRACDAM analysis for loading condition 3

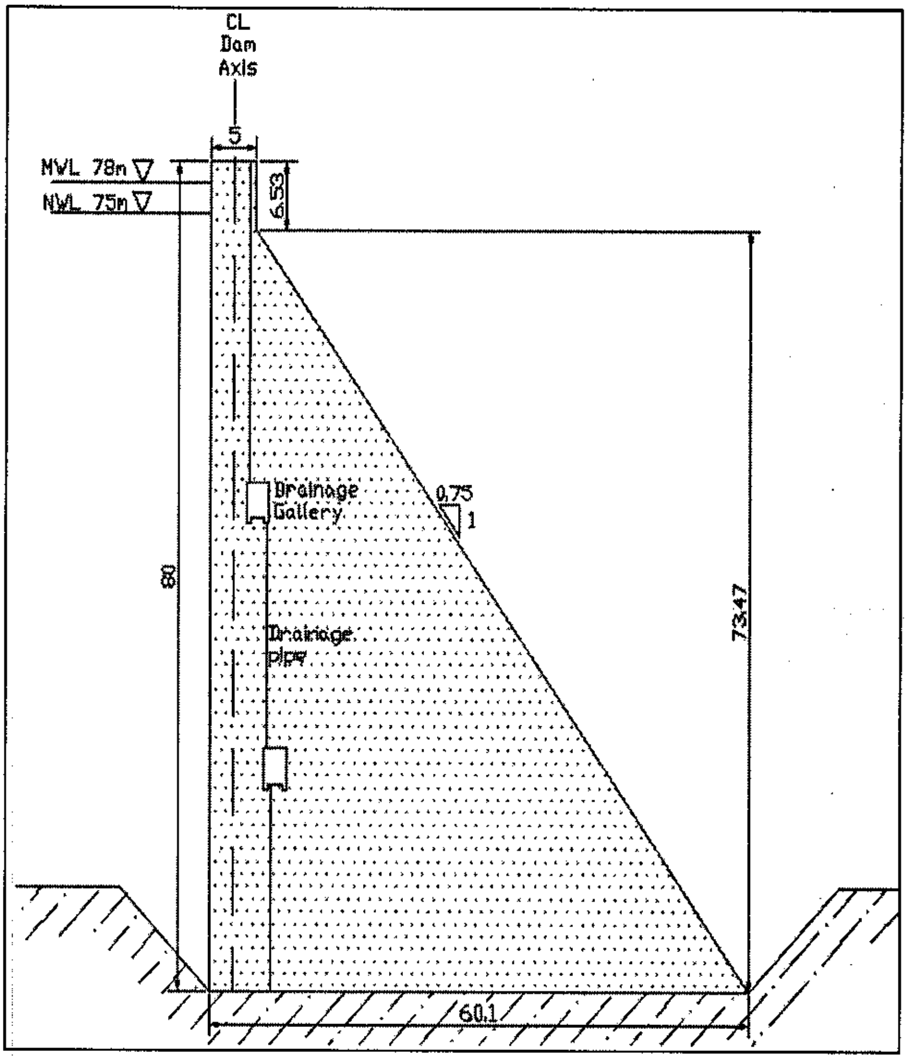


Figure 6.3 – Sg Kinta Dam designed dimension

Under LC3 (Refer Table 6.1), the analysis done resulted a failure of a low minimum principal stress, which is -16.02Kg.f/cm^3, less than the maximum allowable -7Kg.f/cm^3. The analysis done resulted a failure of a low overturning safety factor for this loading condition, which is at 1.38 below the minimum allowable of 1.5. Thus, a change has been made to the dam body dimension. Additional features have been introduced as a solution for the failures. After running again the stability analysis with the new dam dimension, it results a better and no failure record.

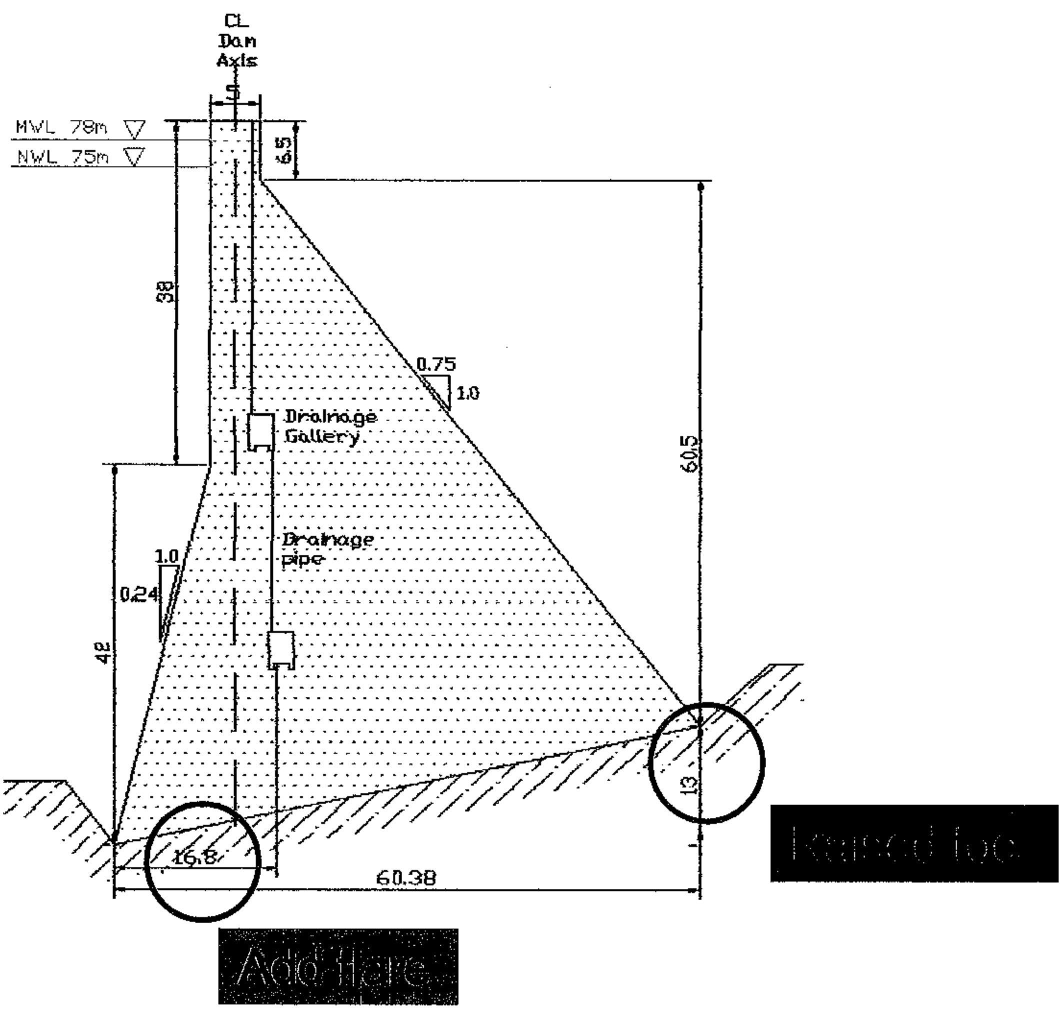


Figure 6.4 – Sg Kinta Dam renovation proposed

7 CONCLUSIONS AND RECOMMENDATIONS

Although RCC dam construction has now developed to the point where gravity dams of any reasonable height and any volume can be constructed with confidence, innovations and developments are still taking place as this technology is still new. The other conclusions are:

- Roller Compacted Concrete (RCC) is a better selection for Concrete Gravity Dam Construction in terms of cost and performance.
- The main factor for the RCC performances are mixing and compacting method, apart from the mix design.
- Roller Compactor is the best compacting method for the RCC layers.
- The Sg Kinta RCC Dam is not stabile under those 2 condition load. One solution to improve the stability is by raise toe and add flare to the body dam.

Roller Compacted Concrete (RCC) construction techniques used result in a much lower unit cost per cubic yard compared with conventional concrete placement methods.

There are also some recommendations from the study, which are:

- RCC should be applied to other area such as parking lot, road pavement etc due to economic reason.
- More experiments should be conducted to investigate the properties of the RCC.
- Civil Eng Dept should buy more concrete technology equipment for the study/project feasibility in the future. This machine including Roler Compactor, Mixer, Coring Machine etc.
- RCC should also be included in the Concrete Technology syllabus to expose the student about the RCC technologies and applications.

8. REFERENCES

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3. **A.M Neville & J.J Brooks**, "*Concrete Technology*" Pearson Education.Limited, 1990.]

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7. **Brian A Forbes**, " Construction of Ralco Dam in Southern Chile", International seminar of RCC Dam, San Diego, California, Aug 2002

8. **Dr. M.R.H Dunstan,** "Recent Developments in RCC Dams", International Journal on Hydropower & Dams, Issue 1 Volume 6, 1999.

9. **Brian A Forbes," High RCC standard achieved at Jordan's Tannur Dam,"** GHD Pty Ltd, Australia, ICOLD Bulletin, Issue Three 2001.

10. **BS1881: 1983 – British Standard for Concrete**

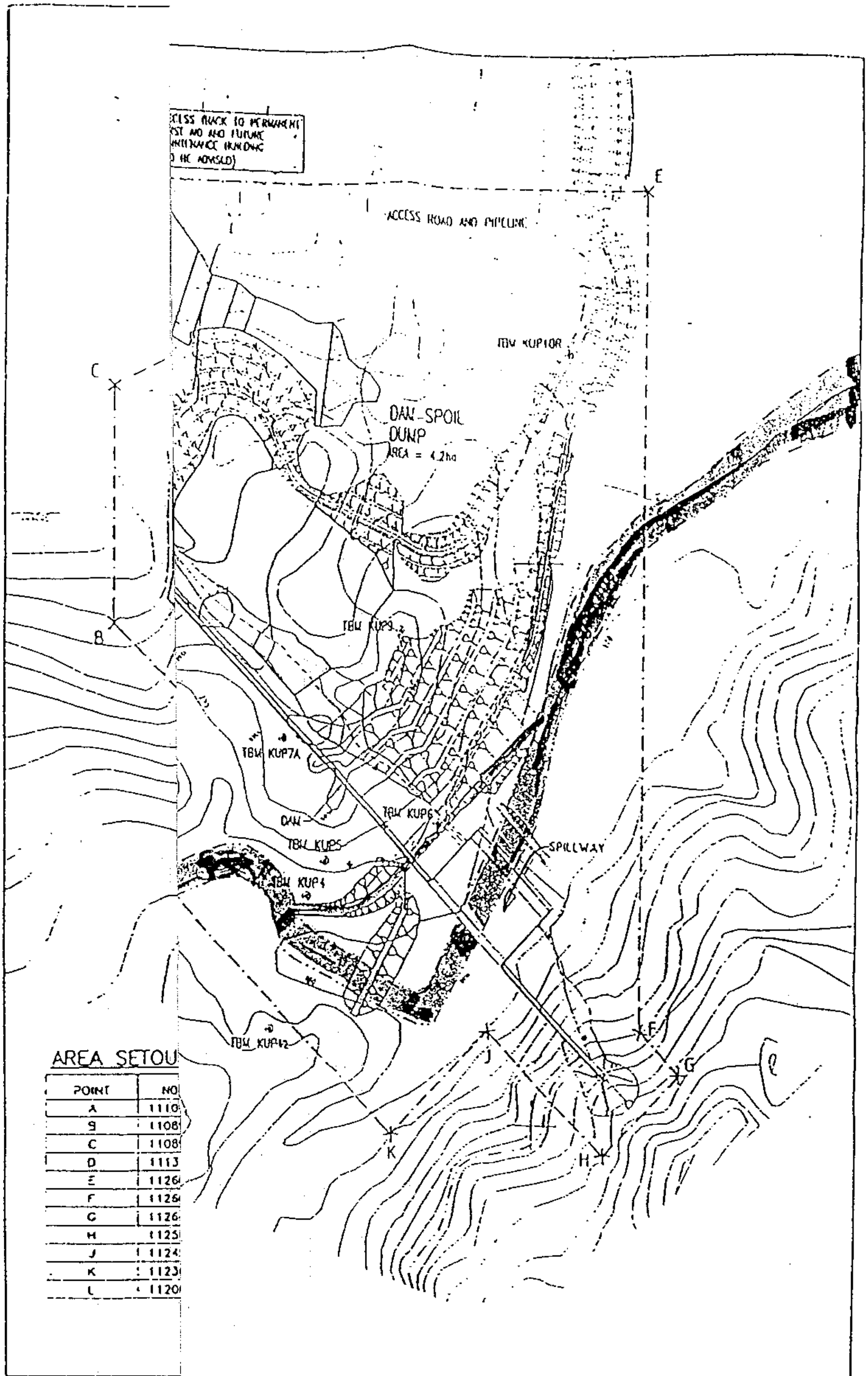
9.1 – SG KINTA RCC DAM PROJECT PLAN

SG KINTA DAM PROJECT

CONTRACT	:	CONSTRUCTION OF SUNGAI KINTA DAM AND ASSOCIATED WORKS
CONTRACT AMOUNT	:	RM149,500,000.00
CONTRACTOR	:	SERIBONG-KONBINA-HAZAMA CONSORTIUM
DATE OF POSESSION OF SITE	:	27 JANUARY 2003
DATE OF COMPLETION	:	27 NOVEMBER 2005

PHYSICAL DETAILS

1) LOCATION	:	21KM NORTH-EAST OF IPOH
2) RIVER SYSTEM	:	SUNGAI KINTA
3) TYPE OF DAM	:	ROLLER COMPACTED CONCRETE DAM
i) Height (m)	:	80M
ii) Crest Length (m)	:	760M
iii) Crest Level	:	250M
4) SPILLWAY		
i) Type	:	OGEE CREST
ii) Length (m)	:	100M
iii) Crest Level	:	245M
5) RESERVOIR		
i) Maximum Level	:	RL250M
ii) Full Supply Level	:	RL245M
iii) Minimum Operating Level	:	RL190M
iv) Storage at Full Supply Level (Mm^3)	:	$29.9Mm^3$
v) Reservoir Surface Area at FSL	:	101HA
6) CATCHMENT AREA		
i) At Dam Site	:	146sq Km



AREA SETOU

POINT	NO
A	1110
B	1108
C	1108
D	1113
E	1126
F	1126
G	1126
H	1125
J	1124
K	1123
L	1120

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D ENGINEERS SDN BHD
&
oskins & Davey Pty. Ltd.

METROPOLITAN UTILITIES CORPORATIONS SDN BHD

GREATER IPOH WATER SUPPLY SCHEME II
SG. KINTA DAM PROJECT

DRAWN	CHECKED
SUBMITTED	APPROVED

CONTRACT NO. CWSK/SK/DAM-004

DRAWING NO. 733482-003

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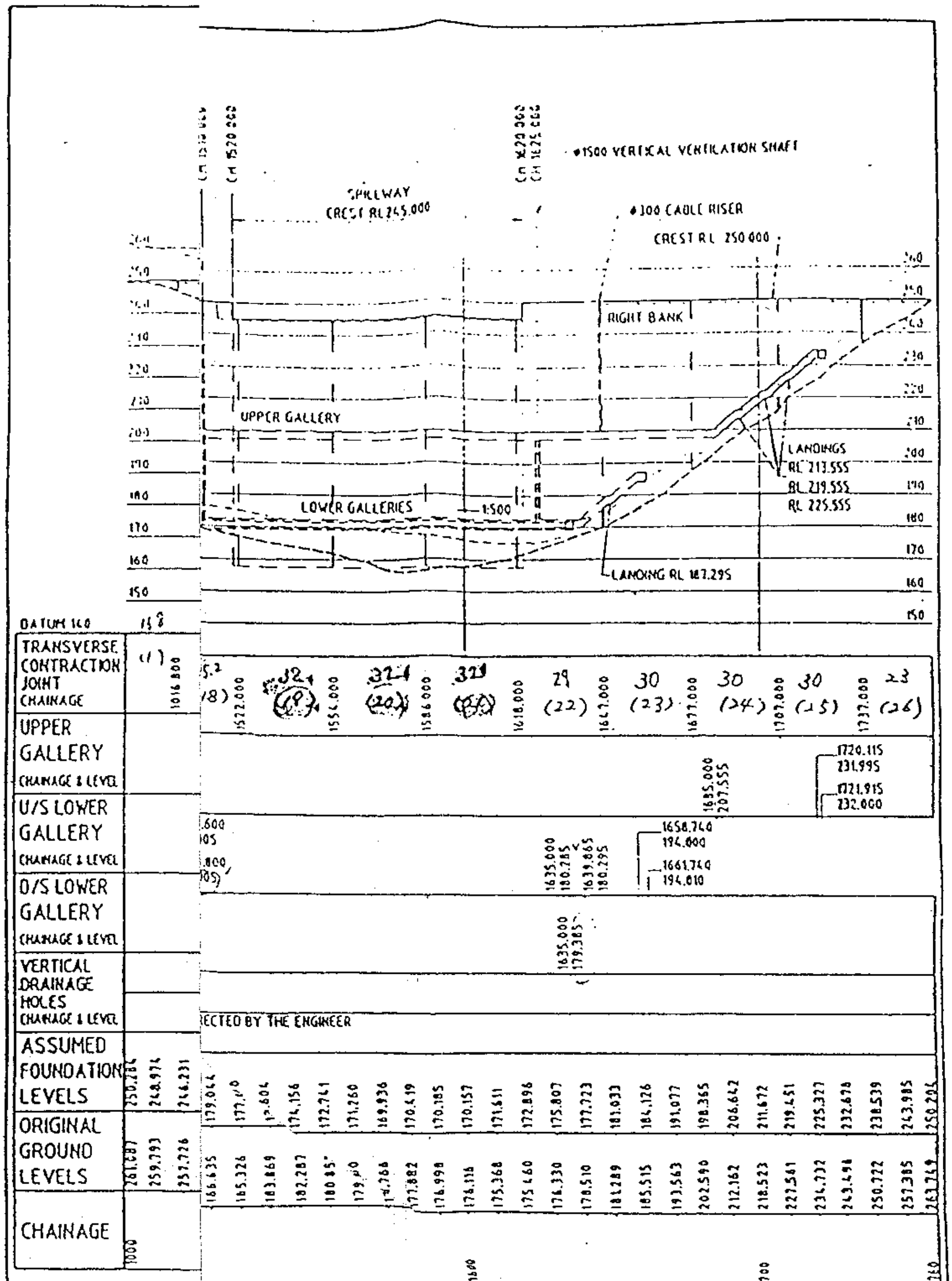

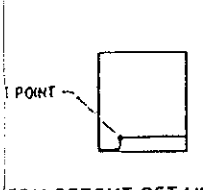

ERY SETOUT DETAIL

NOTES:

1. TRANSVERSE CONTRACTION JOINT LOCATIONS MAY BE VARIED AS DIRECTED BY THE ENGINEER.
2. FOR ACCESS GALLERY DETAILS REFER DWG No.733482-055.
3. FOR GALLERY DETAILS REFER DWG No.733482-070.
4. FOR VENTILATION SHAFT RECESS REFER DWG 733482-071.
5. FOR WATERSTOP DETAILS REFER DWG No.733482-063.
6. FOR ø300 CABLE RISER DETAILS REFER DWG No.733482-058 & 071.
7. FOR NOTES REFER TO DWG No. 733482-002.

ISSUE FOR TENDER

) ENGINEERS SDN BHD
&
askins & Dovey Pty. Ltd.

DO NOT SCAL

DRAWN	CHECKED	METROPOLITAN UTILITIES CORPORATIONS SDN BHD
SUBMITTED	APPROVED	GREATER IPOH WATER SUPPLY SCHEME II SG. KINTA DAM PROJECT
CONTRACT NO. GIWSS/SK/DAM-004	DRAWING NO.	733482-051

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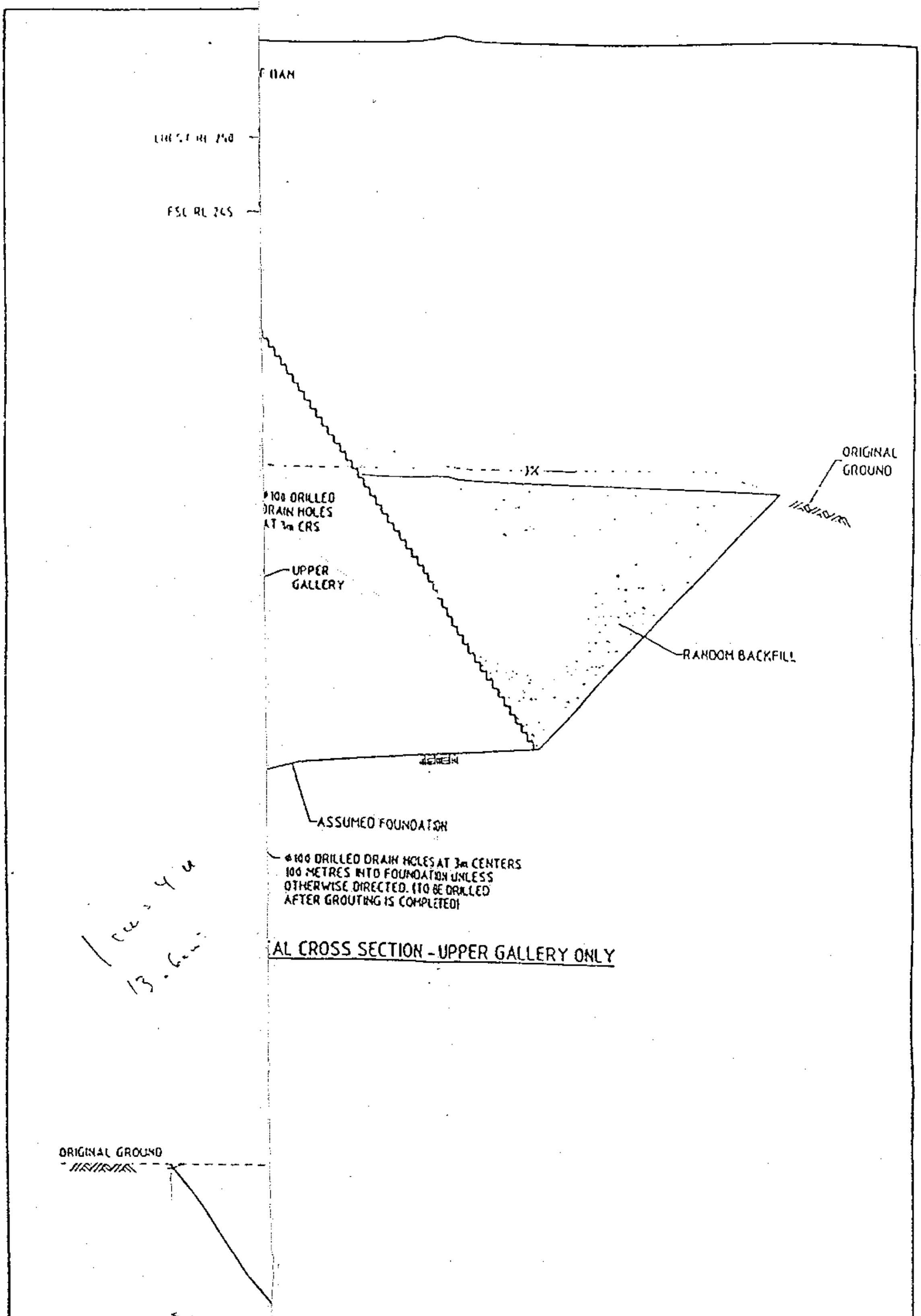

ISSUE FOR TENDER

NOTES:

1. FOR GALLERY SETOUT DETAILS REFER DWG No.733482-051.
2. FOR NOTES REFER TO DWG No. 733482-002.

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SCALE IN METRES (1:200 FULL SIZE A1)

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NEERS SDN BHD

& Davey Pty. Ltd.

CHECKED

APPROVED

METROPOLITAN UTILITIES CORPORATIONS SDN BHD

GREATER IPOH WATER SUPPLY SCHEME II

SG. KINTA DAM PROJECT

CONTRACT NO. GWSII/SK/DAM-001

DRAWING NO. 733482-053

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9.2- FIGURE OF SG KINTA RCC DAM CONSTRUCTION PROGRESS

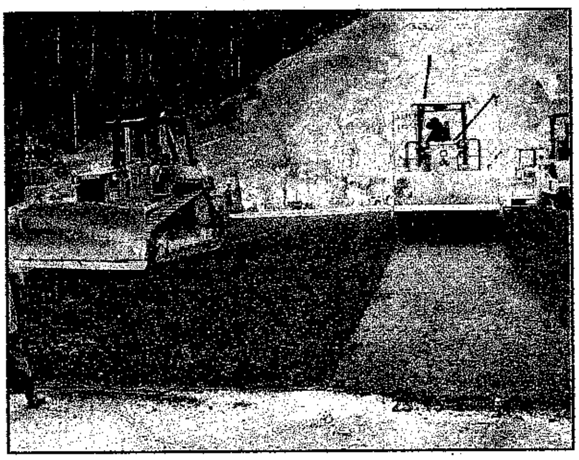

Figure 1 – Spreading and compacting the RCC layer 23-10-04

Figure 2 – Previous RCC layer, mortar and fresh incompact RCC 23-10-04

Figure 3 – RCC layer surface 23-10-04

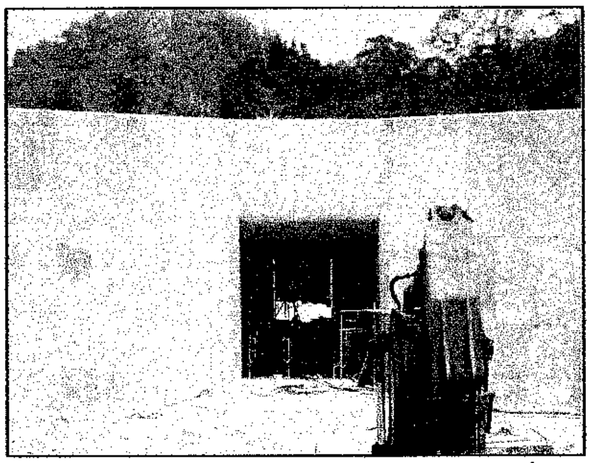

Figure 4 – Diversion culvert under construction (28th Feb 2004)

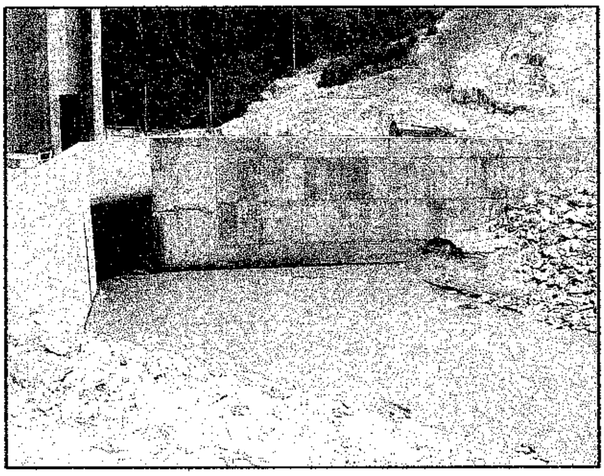

Figure 5 – Operating Diversion Culvert (8th Sept 2004)

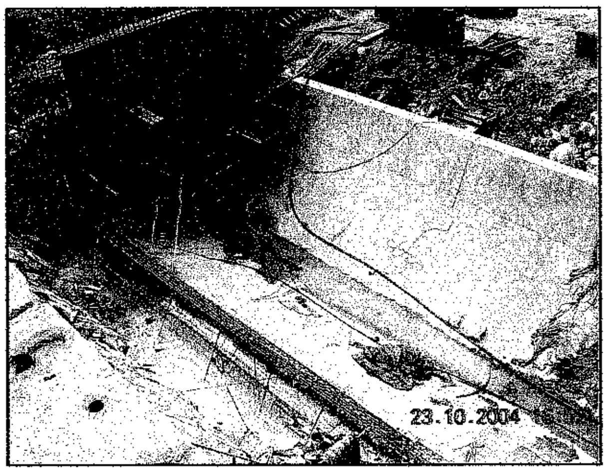

Figure 6 – Spillway under construction 23-10-04

Figure 7 – Water intake tower above the diversion culvert 8-9-04

Figure 8 – Laser Guide system for ensure RCC spreading is uniform 23-10-04

Figure 9 – Dumper Truck 23-10-04

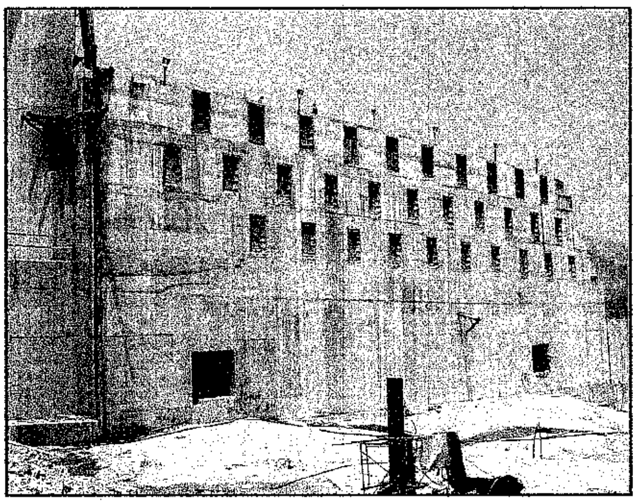

Figure 10 – Dam body interlocking wall system 8-9-04

Figure 11 – Vebe test apparatus

Figure 12 – Dam foundation works (28th Feb 2004)

Figure 13 – Dam body construction (3rd Nov 2004)

Figure 14 – Dam left abutment 28-2-04

Figure 15 – Dam Right abutment 28-2-04

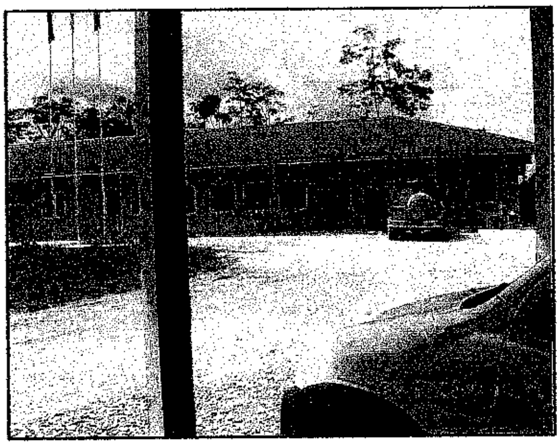

Figure 16 – Project site office

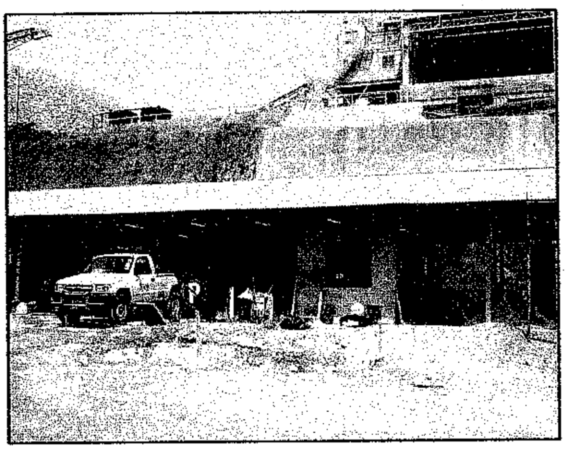

Figure 17 – Site laboratory

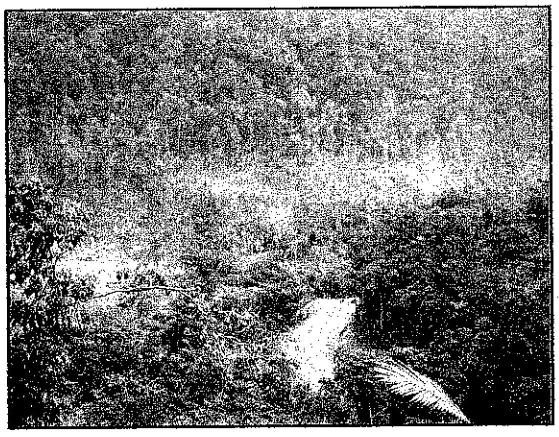

Figure 18 – Upstream valley to be water reservoir 28-2-04

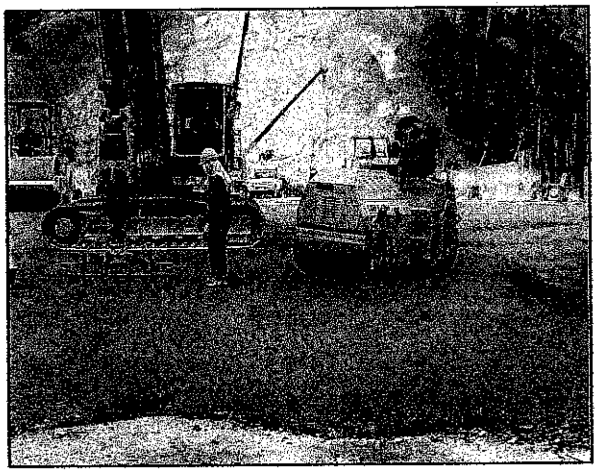

Figure 19 – Small compactor for small space area

Figure 20 – Dam sensor instrumental system 23-10-04

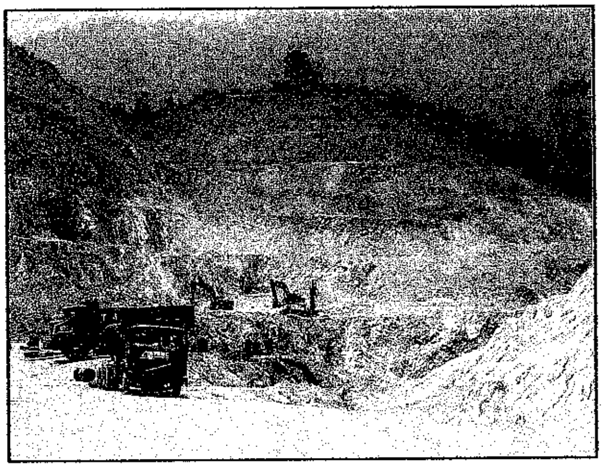

Figure 21 – Nearby quarry for granite supply 23-10-04

9.3 – CHARACTERISTIC OF THE EXISTING DAMS IN MALAYSIA

Summary of existing dam characteristics in Malaysia

No.	Dam Number	Name of Dam	State	River System	Type of Dam	Heigth (m)	Dam Crest Length(m)	Purpose of Dam	Year of Completion	Reservoir Full Storage Level (M)	Storage Capacity at FSL (M.cum)	Spillway Type	Spillway Discharge Capacity
1	A-01	Air Kuning	Perak	Sg. Ranting	E	18.00	520.00	W	1991	34.00	1.80	S	7.70
2	A-02	Bersia	Perak	Sg. Perak	E	33.00	252.00	H,F	1983	141.50	70.00	GC	5280.00
3	A-03	Bukit Merah	Perak	Sg. Kurau	E	9.10	610.00	I,W	1906	8.70	75.00	GC	424.00
4	A-04	Chenderoh	Perak	Sg. Perak	C	32.00	290.00	H,F	1930	60.40	95.40	US	14700.00
5	A-05	Gopeng	Perak	Sg. Gopeng	E	9.00	85.00	SR	1961	-	-	SU	78.00
6	A-06	Jor	Perak	Sg. Btg. Padang	E	45.70	210.00	H,F	1967	493.50	3.90	GC	1104.00
7	A-07	Kenering	Perak	Sg. Perak	E	48.00	503.00	H,F	1983	111.30	352.00	SU	8960.00
8	A-08	Mahang	Perak	Sg. Mahang	E	21.00	230.00	H	1967	71.60	0.40	CU	50.00
9	A-09	Temenggor	Perak	Sg. Perak	R	127.00	357.00	H,F	1978	248.80	6168.00	-	2830.00
10	A-10	Kinta	Perak	Sg. Kinta	RCC	80.00	760.00	W	2006	30.00	-	CU	-
11	B-01	Air Kuning	Selangor	Sg. Air Kuning	C	10.00	50.00	Re	1934	31.00	0.08	UC	-
12	B-02	Batu	Selangor	Sg. Kelang	E	44.00	550.00	F,W	1986	-	36.00	S	193.00
13	B-03	Damansara	Selangor	Sg. Damansara	E	18.00	123.00	W	1962	41.00	0.01	GC,S	-
14	B-04	Klang Gates	Selangor	Sg. Kelang	C,A	37.00	139.00	W,F	1959	95.22	28.51	UC	340.00
15	B-05	Langat	Selangor	Sg. Langat	E	61.00	366.00	W	1979	221.00	35.49	S	520.00
16	B-06	Meru	Selangor	Sg. Subang	E	9.10	127.00	W	1950	37.80	3.50	UC	139.90
17	B-07	Semenyih	Selangor	Sg. Langat	E	49.00	800.00	W	1985	111.00	62.60	S	60.00
18	B-08	Sungai Baru	Selangor	Sg. Baru	C	10.30	67.00	Re	1934	37.80	0.15	C	-
19	B-09	Sungai Tinggi	Selangor	Sg. Tinggi	E	36.00	280.00	W	1996	57.00	107.50	UC	182.00
20	B-10	Sg. Selangor	Selangor	Sg. Selangor	E	110.00	800.00	W	2003	220.00	235.00	UC	3000.00
21	C-01	Aanak Endau	Pahang	Sg. Anak Endau	E	18.00	700.00	I,W	1985	19.00	38.00	S	250.00
22	C-02	Pontian	Pahang	Sg. Pontian	E	15.50	350.00	I,W	1985	5.00	40.00	S	605.00
23	C-03	Repas Baru	Pahang	Sg. Rengas	E	20.00	40.00	SR	1963	102.70	0.40	GC	85.00
24	C-04	Repas Lama	Pahang	Sg. Bentong	E	13.40	210.00	SR	1925	-	-	UC	60.00
25	C-05	Sultan Abu Bakar	Pahang	Sg. Bertam	C	40.00	135.00	H	1963	1070.80	6.70	C	963.00
26	C-06	Chereh Dam	Pahang	Sg. Golok	E	45.00	400.00	W	2004	79.10	250.00	S	1223.00
27	D-01	Bukit Kwong	Kelantan	Sg. Chereh	E	7.70	2000.00	I,W	1979	16.76	14.30	UC	48.00
28	D-02	Pergau (Kuala Yong)	Kelantan	SG. Pergau	E	75.00	750.00	H,F	1996	636.00	62.50	UC	2403.00
29	J-01	Bekok	Johor	Sg Batu Pahat	E	15.00	4320.00	F,W	1990	13.30	32.00	UC	1152.00
30	J-02	Congok (Tenglu)	Johor	Sg Tenglu	E	2.00	700.00	W	1960	500.00	0.95	C	234.00
31	J-03	Gunong Ledang	Johor	Sg Muar	C	10.50	79.40	W	1959	-	0.30	UC	-
32	J-04	Juaseh	Johor	Sg Juaseh	E	29.50	220.00	W	-	82.50	33.20	GC	382.00
33	J-05	Labong	Johor	Sg Endau	E	9.30	250.00	I,W	1949	8.00	11.54	UC	85.00
34	J-06	Layang (Lower)	Johor	Sg Layang	E	8.00	600.00	W	1989	6.00	11.63	S	385.00
35	J-07	Layang (upper)	Johor	Sg Layang	E	26.00	600.00	W	1985	26.60	45.00	C	269.00
36	J-08	Lebam	Johor	Sg Lebam	E	13.00	380.00	W	1979	11.60	3.10	GC	212.20
37	J-09	Linggiu	Johor	Sg Linggiu	E	39.00	51.00	W	1984	1.00lsd	772.00	UC	533.00
38	J-10	Machap	Johor	Sg Benut	E	11.50	550.00	F,W	1982	15.85	12.30	UC	306.00
39	J-11	Pengkalan Bukit (Lower)	Johor	Sg Muar	C	4.50	55.70	W	1912	-	0.01	UC	-
40	J-12	Pengkalan Bukit (upper)	Johor	Sg Muar	C	12.00	64.00	W	1950	-	0.15	-	-
41	J-13	Semberong	Johor	Sg Batu Pahat	E	11.00	1975.00	F,W	1984	8.50	18.00	UC	350.00

Notes: Type of Dam : E – Earth fill, C – Concrete, R – Rock fill, C,A – Concrete Arch, C,B – Concrete Buttress
Spillway Type : G – Gated, U – Ungated, C – Chute
Purpose of Dam : W – Water Supply, I – Irrigation, H – Hydropower, F – Flood Control, Re – Recreation, SR – Silt Retention

(Malaysia Water Industry Guide 2003)

No.	Dam Number	Name of Dam	State	River System	Type of Dam	Heigth (m)	Dam Crest Length(m)	Purpose of Dam	Year of Completion	Reservoir Full Storage Level (M)	Storage Capacity at FSL (M.cum)	Spillway Type	Spillway Discharge Capacity
42	K-01	Ahning	Kedah	Sg. Kedah	R	74.00	270.00	W,I	1986	113.00	275.00	S	115.00
43	K-02	Malut	Kedah	Sg. Malut	E	40.00	265.00	W,I	1987	76.00	7.16	U	150.00
44	K-03	Muda	Kedah	Sg. Muda	C,B	36.00	90.00	I	1968	100.60	160.00	UC	1982.19
45	K-04	Padang Saga	Kedah	Sg. Ulu Melaka	E	8.30	200.00	I,W	1964	21.18	0.20	U	57.00
46	K-05	Pedu	Kedah	Sg. Kedah	E	61.00	38.00	I	1969	97.50	1073.00	S	2831.70
47	L-01	Bukit Kuda	Labuan	Sg. Bangat	E	10.36	205.70	W	1984	13.40	4.78	U	15.10
48	L-02	Kerupang	Labuan	Sg. Kerupang	E	13.72	115.82	W	1984	14.30	0.21	S	5.10
49	L-03	Pagar	Labuan	Sg. Pagar	E	14.63	130.95	W	1984	14.30	0.41	S	7.65
50	M-01	Air Keroh	Melaka	Sg. Melaka	E	7.00	12.00	Re	1890	20.73	n.a	UC	n.a
51	M-02	Asahan	Melaka	Sg. Kesang	E	8.00	310.00	W	1932	70.96	0.70	S	n.a
52	M-03	Durian Tunggal	Melaka	Sg. Melaka	E	23.00	224.00	W	1977	28.41	32.60	C	453.00
53	N-01	Kelinci	N. Sembilan	Sg. Kelinci	E	70.00	270.00	W	1998	215.00	50.00	UC	576.00
54	N-02	Pedas (New)	N. Sembilan	Sg. Beringin	C	22.00	141.00	W	1990	135.00	0.53	S	215.00
55	N-03	Sg. Terip	N. Sembilan	Sg. Terip	E	43.00	500.00	W,I	1987	103.00	48.00	C	340.00
56	N-04	Upper Muar	N. Sembilan	Sg. Muar	E	52.00	300.00	W	1992	154.00	53.00	C	2150.00
57	N-05	Gemencheh	N. Sembilan	Sg. Gemencheh	E	39.00	270.00	W	1999	110.00	30.80	S	230.00
58	P-01	Air Hitam	P.Pinang	Sg. Air Hitam	E	47.30	245.00	W	1963	234.00	2.60	S	115.00
59	P-02	Mengkuang	P.Pinang	Sg. Kulim	E	31.00	1006.00	W	1985	43.30	23.60	OC	11.60
60	P-03	Teluk Bahang	P.Pinang	Sg. Teluk Bahang	E	58.00	700.00	W	1999	48.00	21.00	GC	320.00
61	R-01	Timah Tasoh	Perlis	Sg. Perlis	E	13.50	3500.00	I,W,F	n.a.	29.10	40.00	S	418.00
62	S-01	Babagon	Sabah	Sg. Babagon	R	50.00	133.00	W	1997	128.00	21.50	C	n.a.
63	S-02	Pinangsoo	Sabah	n.a.	E	12.00	65.00	W	1969	15.24	0.24	S	n.a.
64	S-03	Sepagay (lahad Datu)	Sabah	Sg. Silibukan	R	22.86	73.15	W	1984	80.00	2.50	C	n.a.
65	S-04	Tenom	Sabah	Sg. Pedas	C	n.a.	83.00	H	1984	173.90	4.70	U	n.a.
66	S-05	Timbangan (Semporna)	Sabah	Sg. Kalumpang	C	15.24	156.00	W	1984	55.50	0.67	G	162.00
67	SK-01	Batang Al	Sarawak	Sg. Batang Al	R	85.00	680.00	H	1985	112.00	2800.00	C	2613.00
68	SK-02	Sika (Bintulu)	Sarawak	Sg. Sika	E	27.00	270.00	W	1985	2000.00	3280.00	S	n.a.
69	T-01	Bukit Bauk Bunded Storage	Terengganu	-	E	9.00	10.00	W	1986	7.50	0.19	S	n.a.
70	T-02	Kemaman Bunded Storage	Terengganu	Sg. Kemaman	E	8.00	120.00	W	1985	8.75	0.13	CU	n.a.
71	T-03	Kenyir	Terengganu	Sg. Terengganu	R	155.00	800.00	H,F	1984	145.00	13600.00	S	6500.00
72	T-04	Serdang Bunded Storage	Terengganu	-	E	27.50	846.00	W	1986	7.50	0.19	n.a.	n.a.

Notes: Type of Dam : E – Earth fill C – Concrete R – Rock fill C, A – Concrete Arch C, B – Concrete Buttress
Spillway Type : G – Gated U – Ungated C – Chute
Purpose of Dam : W – Water Supply I – Irrigation H – Hydropower F – Flood Control Re – Recreation SR – Silt Retention

(Malaysia Water Industry Guide 2003)

9.4 – PROCEDURES OF EXPERIMENTS AND LABORATORY TESTING

Fly Ash

Fly ashes are finely divided residue resulting from the combustion of ground or powdered coal. They are generally finer than cement and consist mainly of glassy-spherical particles. Use of fly ash in concrete started in United States in the early 1930's. The first comprehensive study was that describe in 1937 by R.E Davis. The major breakthrough in using fly ash in concrete was the construction of Hungry Horse Dam in 1948, utilizing 120 000 metric tons of fly ash.

In addition to the economic and ecological benefits, the use of fly ash in concrete improve its workability, reduces segregation, bleeding, heat evolution and permeability, alkali-aggregate reaction, and enhances sulfate resistance.

Two major classes of fly ash are specified, these are specified as Class F & Class C. Class F is fly ash normally produced from burning anthracite or bituminous coal. Class C is normally produced from the burning of sub bituminous coal and lignite. Class C fly ash usually has cementitious properties due to free lime, whereas Class F is rarely cementitious when mixed water alone.

Because fly ash use displaces cement use, it also reduces the need for cement production – a major energy user and source of "greenhouse gas" emissions. For every ton of cement manufactured, about 6.5 million BTUs of energy are consumed. For every ton of cement manufactured, about one ton of carbon dioxide is released. Replacing that ton of cement with fly ash would save enough electricity to power the average American home for 24 days, and reduce carbon dioxide emissions equal to two months use of an automobile.

Experts estimate that cement production contributes to about 7 percent of carbon dioxide emissions from human sources. If all the fly ash generated each year were used in producing concrete, the reduction of carbon dioxide released because of decreased cement production would be equivalent to eliminating 25 percent of the world's vehicles.

Air Entraining Agent

Retention of the air in the concrete is the mechanic entraining of the large and well distributed number of the minuscule air bubble during the moisture of the concrete, produced through the entraining of the appropriate air agent.

It is very important the entraining of the air in the concrete that due to the float of the minuscule bubbles of air that are distributed in the mixture, the sedimentation of the solid particulars id delayed.

The "bleeding" is reduced, providing a better quality of the concrete. Besides a better resistance to freezing and defrosting as well the plasticity characteristics, uniformity and cohesion the areas type honey-comb (areas of great space) due to the wrong consolidation of putting the concrete are reduced and sometimes eliminate with the entraining of the air, improving the general quality of the structure.

There are several items that have influence in the quality of the entrained air as:

Composition of the moisture, consistence of the concrete, temperature, vibration, classification of the type and size of the agglomerate and others items and therefore one must look for the better conditions.

The air entraining agents have large use in foundations of the concrete, slabs, dikes, tunnels, canals, bridges and other, also specific for concrete highways projects.

2.3.2 Compressive Strength

The relationship between water-cement ratio and compressive strength is the same for RCC as for conventional mass concrete. Normally, for durability reasons, the RCC mix will be designed to provide a minimum strength of 2,000 psi; however, for

4.2 Experiment and Analysis

The student experiences most of related tasting and experiment that carried out at the site laboratory. The testing was done daily, base on the RCC production on the site. The result gathered is basically to keep a RCC quality within an acceptable range as designed. The further comparison analysis will be done base on the test result.

4.3 Stability Analysis

The stability analysis of the dam will be done by using the existing GRACDAM will be developed throughout the project period. A preliminary cost analysis of the design compared to some possible analysis will also be made.

5 EXPERIMENTAL WORKS

5.1 Equipment and Facilities

The machine used for all the related testing and experiments of this study are as below:

5.1.2 CONCRETE DRUM MIXER

5.1.3 SPLIT CYLINDER TEST PLATENS

5.1.4 500 KN COMPRESSION MACHINE

5.1.5 VEBE APPARATUS

5.1.6 COMPACTOR

5.1.6.1 PLATE COMPACTOR

5.1.6.2 LIGHT HAND COMPACTOR (RECTANGULAR PLATE)

5.1.6.3 HEAVY HAND COMPACTOR (ROUND PLATE)

5.1.7 CORING MACHINE

5.1.8 POKER VIBRATOR

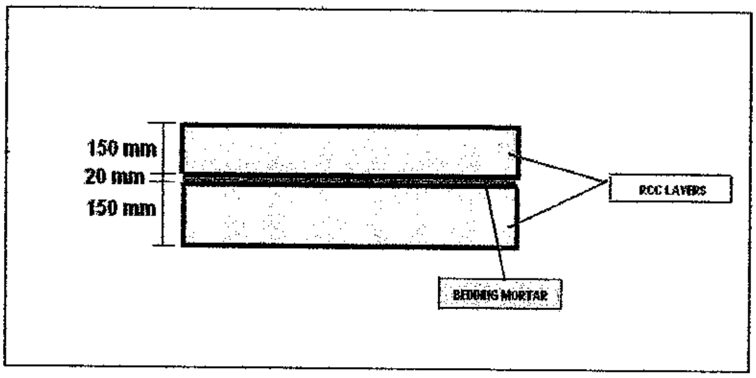

Figure 5.33 - RCC Layers Diagram

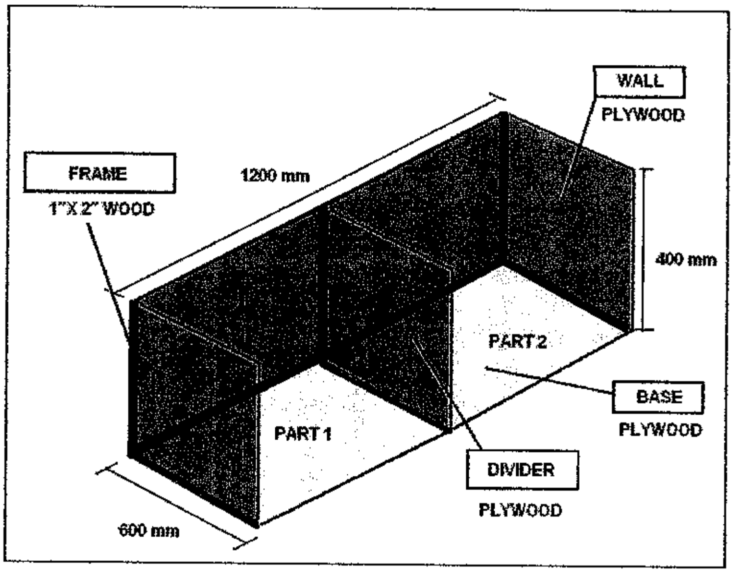

Figure 5.34 - RCC layers formwork – 3D view

Figure 5.35- Roller Compactor for the top layer of the model

6 SG KINTA RCC DAM STABILTITY ANALYSIS

In GRACDAM, the formulas used to obtain the values are using the USBR Gravity Method. The program calculates the stresses and safety factors of a gravity dam at its base. There are 9 loading conditions perform by the GRACDAM, there are:

Table 6.1 - GRACDAM loading combinations

No.	Reservoir	Uplift	Drains	Silt	Earthquake V.H
1	N	Y	Y	Y	-
2	M	Y	Y	Y	-
3	N	Y	Y	Y	U.E
4	M	Y	-	Y	-
5	N	Y	-	Y	U.E
6	E	-	-	-	U.W
7	E	-	-	-	D.W
8	N	-	-	Y	D.E
9	M	-	-	Y	-

Where:

N = Normal Water Level, NWL (Full Supply Level, FSL)

M = Maximum Water Level, MWL

Uplift = uplift pressure

Drains = drainage galleries

Silt = silt pressure

Earthquake = earthquake pressure

U = upward earthquake vertical acceleration (referring to the inertia of the dam instead to the movement of the earthquake)

D = downward earthquake vertical acceleration (referring to the inertia of the dam instead to the movement of the earthquake)

E = east or upstream earthquake horizontal acceleration (referring to the inertia of the dam instead to the movement of the earthquake)

W = east or downstream earthquake horizontal acceleration (referring to the inertia of the dam instead to the movement of the earthquake)

GRACDAM calculate the stresses at the heel and toe of the dam. The stresses calculated are:

- Compressive stress
- Principal (normal) stress
- Principal (shear) stress

Besides that, 3 safety factors analyse by GRACDAM are:

- Safety factor against overturning
- Safety factor against sliding
- Safety factor against shear

Values calculated (stresses and safety factors) are compared to the limit set for each condition. If any value exceeds the prescribed limit, a "WARNING" notation appears. Sample of the output results of GRACDAM analysis on the Sg Kinta RCC Dam is attached on the next page.

Analysis was made using GRACDAM on the stability of Kinta Dam, the first Roller Compacted Concrete (RCC) dam in Malaysia. But due to some limitation, on the study of the properties of RCC compared to conventional concrete, the analysis was made by assuming that Kinta Dam is made from conventional concrete.

The stability analysis is done by using the dimension as shown below. This is the preliminary design of the dam. Under LC1 (Refer Table 6.1), the analysis done resulted a failure of a low overturning safety factor, which is 2.38 below the minimum allowable of 2.5.

References Web site:

1. www.usace.army.mil
2. www.hydropower-dams.com
3. www.concrete.org
4. www.icold.com
5. www.britishdams.org
6. www.intertechne.com.br

9. LIST OF APPENDICES

9.1 Sg Kinta Dam Project plan

9.2 Figure of Sg Kinta Dam Project construction progress

9.3 Characteristic of The Existing Dam In Malaysia

9.4 Procedures of Experiments And Laboratory Testing

9.5 Stability Analysis

8. Cover the moulds with polyethylene sheet or damp cloth to prevent evaporation and keep in the curing room for 24 hours.
9. After 24 hours the concrete specimen should be removed from the moulds and stored in the curing tank until they are to be tested at a temperature of 25°C to 5°C.
10. Preferred ages for test are 1, 7, 28, 56 and 90 days for the RCC samples..
11. At least 3 specimens are made for each mix. The total samples made for RCC is 24 cylinders, for both compressive and tensile strength test.

Precaution

1. The fresh concrete samples should be tested for workability before casting. For the RCC, the best method is the Vebe Time Testing.
2. The specimen in the mould should not be moved within the first few hours after casting as this may lead to segregation and excessive bleeding of the concrete.

Compressive Test

Objective

To determine the compressive strength (crushing strength) of concrete according to BS 1881: Part 116: 1983.

Theory

One of the most important properties of concrete is its strength in compression. The strength in compression has a definite relationship with all other properties of concrete. The other properties are improved with the improvement in compressive strength. The compressive strength is taken as the maximum compressive load it a per unit area.

Apparatus

A compression machine testing capacity of 1500KN

Procedure

1. Remove the test cylinder from the curing tank and wipe off surface water with a damp cloth.
2. Weigh the cylinder to the nearest kg.
3. Place the cylinder centrally on the lower platen of the test machine with the rough top surface of the test cube facing towards you.
4. Lower the top platen onto the cylinder and ensure a uniform setting by gently rotating the top platen as it is brought to bear on the cube.
5. Make sure that the test machine is set to the correct loading and pointers are set at zeroes.
6. Apply the load without shock and continuously increase at a rate of 2.10 MPa/s until no greater load can be sustained by the test cube.
7. Record the maximum load carried by each specimen during test.
8. Note the type of failure and appearance of cracks.

Tensile Strength Test

Objective

To determine the split tensile strength of concrete according to BS 1881.

Theory

One of the most important properties of concrete is its strength in tensile. The strength in tensile has a definite relationship with all other properties of concrete. The other properties are improved with the improvement in tensile strength.

Apparatus

A compression machine testing capacity of 1500KN

Procedure

1. Remove the test cylinder from the curing tank and wipe off surface water with a damp cloth.
2. Weigh the cylinder to the nearest kg.
3. Place the cylinder fix to the tensile platen and place it horizontally to the compression machine.
4. Make sure that the test machine is set to the correct loading and pointers are set at zeroes.
5. Apply the load without shock and continuously increase at a rate of 0.7 MPa/s until no greater load can be sustained by the test cube.
6. Record the maximum load carried by each specimen during test.
7. Note the type of failure and appearance of cracks

Procedure of Mixing Conventional Concrete

Objective

To cast and cure test cylinders of a given CC mix.

Apparatus

150 x 300 mm size of steel mould for test cylinders, light hand compactor for finishing.

Procedure

1. The quantity of cement, sand and course aggregate was weighed according to the designed (see table 7).
2. Machine mixing
   i. The drum mixer was ensured clean and dry.
   ii. Concrete ingredients were poured into the mixer and the machine was started and was let to rotate for 1 minute without water.
   iii. Water was added and the mixer was let to rotate for the next1-2 minutes.
   iv. The machine was stopped and the concrete was poured out from onto the non-porous surface.
3. Brush the inner faces of moulds with grease oil and tighten the screws.
4. Fill the mould with concrete sample in layers of 100mm deep approximately.
5. Apply pocket vibrator inside the mould to release air bubbles and make it uniform inside..
6. Repeat the placement of the CC and repeat the compaction work too as above until the third layer..
7. Using a nail mark the top surface of the concrete test cubes to indicate number and date of casting.

8. Cover the moulds with polyethylene sheet or damp cloth to prevent evaporation and keep in the curing room for 24 hours.
9. After 24 hours the concrete specimen should be removed from the moulds and stored in the curing tank of 25°C to 5°C.
10. Preferred ages for test are 1, 7, 28, 56 and 90 days for the CC samples..
11. At least 3 specimens are made for each mix. The total samples made for RCC is 24 cylinders, for both compressive and tensile strength test.

Precaution

1. The fresh concrete samples should be tested for workability before casting. For the CC, the best method is the Slump Test.
2. The specimen in the mould should not be moved within the first few hours after casting as this may lead to segregation and excessive bleeding of the concrete.

Workability slump test

Objectiv

e

To measure the workability of a sample from a batch of fresh concrete

Theory

The measurement of the workability of fresh concrete is important in assessing the practicality of compacting the mix and also in maintaining consistency throughout the job. The slump test is very useful on site as a check of day-today or hour-to-hour variation in the material being fed into mixer. There are three types of slump:

i. True slump

ii. Shear slump

iii. Collapse

Apparatus

The apparatus consists of

- A truncated conical mould 100mm in diameter at the top, 200mm at bottom and 300mm high,
- A steel tamping rod (16mm diameter and 600mm long), rounded at one end,
- A scoop,
- A steel ruler and
- A steel trowel

Procedure of mixing a RCC sample

Objective

To cast and cure test cylinders of a given RCC mix.

Apparatus

150 x 300 mm size of steel mould for test cylinders, A KANGO heavy compactor, water spray, light hand compactor for finishing.

Procedure

1. The quantity of cement, sand and course aggregate was weighed according to the designed.
2. Machine mixing
   1. The drum mixer was ensured clean and dry.
   2. Concrete ingredients were poured into the mixer and the machine was started and was let to rotate for 1 minute without water.
   3. Water was added and the mixer was let to rotate for the next1-2 minutes.
   4. The machine was stopped and the concrete was poured out from onto the non-porous surface.
3. Brush the inner faces of moulds with grease oil and tighten the screws.
4. Fill the mould with concrete sample in layers of 100mm deep approximately.
5. Compact each layer with the round face steel plate compactor 10 seconds for each layer. Apply water spray for each layer before and after the compaction to improve the joint properties of each layer.
6. Repeat the placement of the RCC and repeat the compaction work too as above until the third layer..
7. Using a nail mark the top surface of the concrete test cubes to indicate number and date of casting.

Procedure

1. Clean the inside moulds and places it on a hard, flat and non absorbent surface
2. Take representative sample (about 15kg) from a fresh concrete
3. Fill the mould in four layers of concrete of approximately equal depth (each layer is about 75 mm). Each layer is rodded 25 times with the rounded end of the steel rod. Make sure each rodding passes through the each layer.
4. After the top layer has been rodded, the surface of the concrete is struck off t to level up with the top of the mould.
5. Clean away any spillage of concrete around the base of the mould.
6. Carefully and slowly lift the mould vertically from the concrete. Invert the mould and place it next to the molded concrete. The concrete will slump.
7. Place the rod across the top of the mould.
8. The slum is the difference between the height of the slumped concrete and the mould. Using the steel ruler, measure the slump from the top of the concrete to the underside of the rod.
9. Record the slump to the nearest 5mm.

Compressive strength

Objective

To determine the compressive strength (crushing strength) of concrete according to BS 1881: Part 116: 1983.

Theory

One of the most important properties of concrete is its strength in compression. The strength in compression has a definite relationship with all other properties of concrete. The other properties are improved with the improvement in compressive strength. The compressive strength is taken as the maximum compressive load it a per unit area.

Apparatus

A compression machine testing capacity of 1500KN

Procedure

1. Remove the test cylinder from the curing tank and wipe off surface water with a damp cloth.
2. Weigh the cylinder to the nearest kg.
3. Place the cylinder centrally on the lower platen of the test machine with the rough top surface of the test cube facing towards you.
4. Lower the top platen onto the cylinder and ensure a uniform setting by gently rotating the top platen as it is brought to bear on the cube.
5. Make sure that the test machine is set to the correct loading and pointers are set at zeroes.
6. Apply the load without shock and continuously increase at a rate of 2.10 MPa/s until no greater load can be sustained by the test cube.
7. Record the maximum load carried by each specimen during test.

Note the type of failure and appearance of cracks

Tensile strength

Objective

To determine the split tensile strength of concrete according to BS 1881.

Theory

One of the most important properties of concrete is its strength in tensile. The strength in tensile has a definite relationship with all other properties of concrete. The other properties are improved with the improvement in tensile strength.

Apparatus

A compression machine testing capacity of 1500KN

Procedure

1. Remove the test cylinder from the curing tank and wipe off surface water with a damp cloth.
2. Weigh the cylinder to the nearest kg.
3. Place the cylinder fix to the tensile platen and place it horizontally to the compression machine.
4. Make sure that the test machine is set to the correct loading and pointers are set at zeroes.
5. Apply the load without shock and continuously increase at a rate of 0.7 MPa/s until no greater load can be sustained by the test cube.
6. Record the maximum load carried by each specimen during test.
7. Note the type of failure and appearance of cracks

Experience with RCC layers

Procedure

1. The RCC mix as the normal mixing procedure. For each layer, it is most suitable to do 4 mixing for the required RCC volume. It has to be 4 times mixing due to the limitation of the drum mixer volume.
2. The first layer will be build by using a plate compactor.
3. After finishing the first layer, it will be left dry for some times. Next a 20 mm thickness bedding mortar layer will be spread to the whole surface.
4. Right after that, next RCC layer will be placed shortly. For the next layer, it will be compacted by using a 1 ton roller compactor.

9.5 STABILITY ANALYSIS